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PROJECT DIRECTORS' COMPLETION REPORT D+30 DAYS

(DETONATION RELATED ACTIVITIES)

Project Rio Blanco

JULY 1973

C. E. WILLIAMS
AEC PROJECT DIRECTOR

G. R. LUETKEHANS
CER PROJECT DIRECTOR

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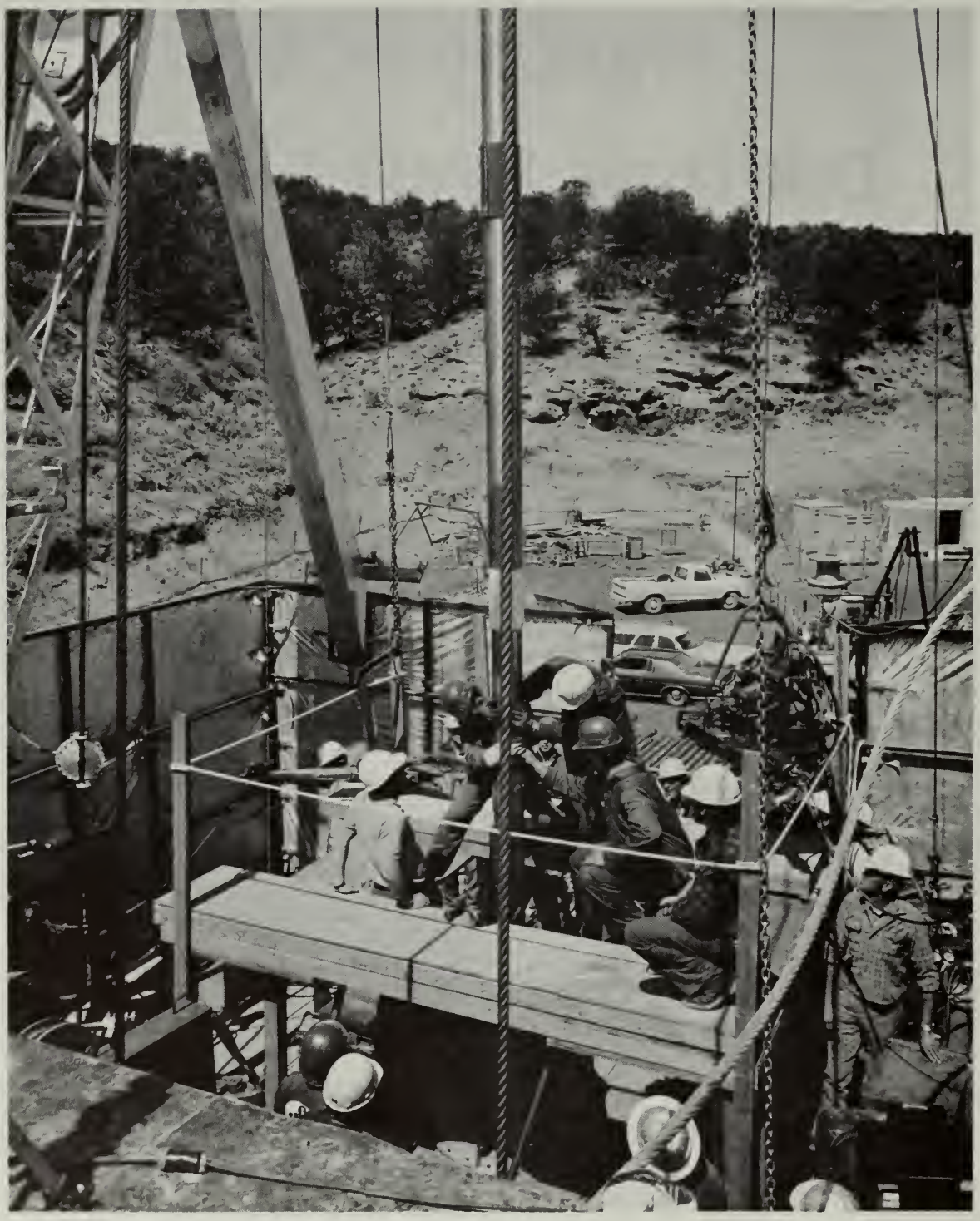

Lowering the Rio Blanco Explosives into the Emplacement Well.

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ABSTRACT

Project Rio Blanco is a Government-Industry gas reservoir stimulation experiment using three 30-kiloton nuclear explosives detonated simultaneously in a single well bore, at depths of 5,840, 6,230, and 6,690 feet. The detonation occurred at 1000:00.12 hours ± .01 second MDT, May 17, 1973, in Rio Blanco County, Colorado. This report summarizes all available project results as of 2400 hours MDT, June 16, 1973. Detailed technical reporting of individual project studies will be available at later times in professional journals and participating organization reports. Evidence to date indicates that there has been no inadvertent release of radiation to the atmosphere, all three explosives detonated and functioned as expected, and no serious architectural or environmental damage occurred. Preliminary seismic estimates indicate that the explosive yields were nominal and the detonation exhibited an equivalent earthquake magnitude of m_b 5.4 (NOAA/National Earthquake Information Center). Rockfalls were not observed beyond approximately 20 miles from the emplacement well. Some minor bioenvironmental effects were evident within a two-mile radius of the emplacement well. Claims for seismic damage in the area have been fewer and less significant than anticipated.

I. INTRODUCTION--Compiled by R. T. Stearns, AEC/NV

The information presented in this report, particularly the results of scientific measurements, is considered to be preliminary. Detailed technical reporting of individual project studies will be made available at later times in professional journals and participating organization reports.

1-1 PROJECT OBJECTIVES

The demand for natural gas throughout the world is increasing at an inordinately rapid rate, particularly in the United States where the current proven recoverable reserves are now sufficient for approximately 11 years. One potential method of augmenting these reserves is the stimulation of highly impermeable or "tight" gas-bearing formations with nuclear explosives.

Project Rio Blanco, sponsored by the CER Geonuclear Corp. (CER) of Las Vegas, Nevada, under a joint venture agreement with the Equity Oil Company of Salt Lake City, Utah, was conducted to stimulate a thick section of low-permeability lenticular gas-bearing sands in the Piceance Creek Basin of West Central Colorado. The experiment involved the simultaneous detonation of three 30-kiloton nuclear explosives emplaced in a vertical bore hole transecting numerous gas-bearing sandstones too "tight" to be produced economically by conventional methods.

Although the primary objective was that of producing gas in commercial quantities from an area not conducive to production by conventional means, there were additional technical objectives of great importance. Some of these were:

(1) The stimulation of a thick gas-bearing interval by the utilization of multiple explosives simultaneously detonated (a method previously not attempted), and subsequent evaluation of its production capacity;

(2) The determination of postdetonation environment characteristics such as interchimney communication, effective heights and volume of the chimneys, and effective fracture zone radii;

(3) The determination of the actual chemical and radiochemical composition of the gas resulting from the detonation;

(4) The development of an emplacement and stemming technique allowing rapid reentry to the stimulated interval.

(5) To reduce tritium production over that experienced on previous gas stimulation projects.

The primary operational objectives were to conduct a project of this nature with minimum impact on the environment and minimum inconvenience to persons living in the area, and to successfully engineer the experiment in order to limit field support costs to the degree necessary to demonstrate the economic viability of the technology. However, numerous delays and the addition of extensive effects measurement programs resulted in a distortion of both engineering and operational costs.

1-2 PROJECT DESCRIPTION

The three nuclear explosives for Project Rio Blanco were detonated at 1000:00.12 hours ± 0.01 seconds, Mountain Daylight Time (MDT), or 1600:00.12 hours ± 0.01 seconds, Greenwich Mean Time (GMT), on May 17, 1973. The three explosives occurred within the Fort Union and Mesaverde formations at depths of 5,840, 6,230, and 6,690 feet. The three explosions occurred nearly simultaneously as planned, and were completely contained. The elevation of the ground at the emplacement well (EW), RB-E-01, is 6,629.9 feet above mean sea level. The EW is located 1,080.5 feet south of the north line and 1,188.5 feet east of the west line in Section 14, Township 3 South, Range 98 West of 6th Prime Meridian (P.M.), Rio Blanco County, Colorado, which corresponds to geodetic coordinates 108°21'59" west longitude and 39°47'35" north latitude. The EW was approximately 52 miles from Grand Junction, 31 miles from Rangely, 30 miles from Meeker, and 37 miles from Rifle, all in Colorado (see location map in Figure I-1).

The spacings and depths of the explosives were designed to create continuous fractures through a 1,300-foot vertical interval of gas-bearing sands. The diameter of the effective fracture zone was expected to be approximately 520 feet. Recent calculations, however, indicate the fracture zone radius may be as large as 800 feet. If the reservoir characteristics are as expected, the Rio Blanco well will be capable of producing approximately 17.5 billion SCF of gas over a 25-year period.

Drillback into the top of the chimney is expected to begin in August, 1973. High flow production testing will be accomplished subsequent to drillback and be completed by late September. It is expected that over 300 million SCF of gas will be flared over a 10-day period. The flow tests and subsequent pressure buildup measurements are designed to determine the technical success of Project Rio Blanco, and to provide data for a determination of the economic viability of gas stimulation using nuclear explosives.

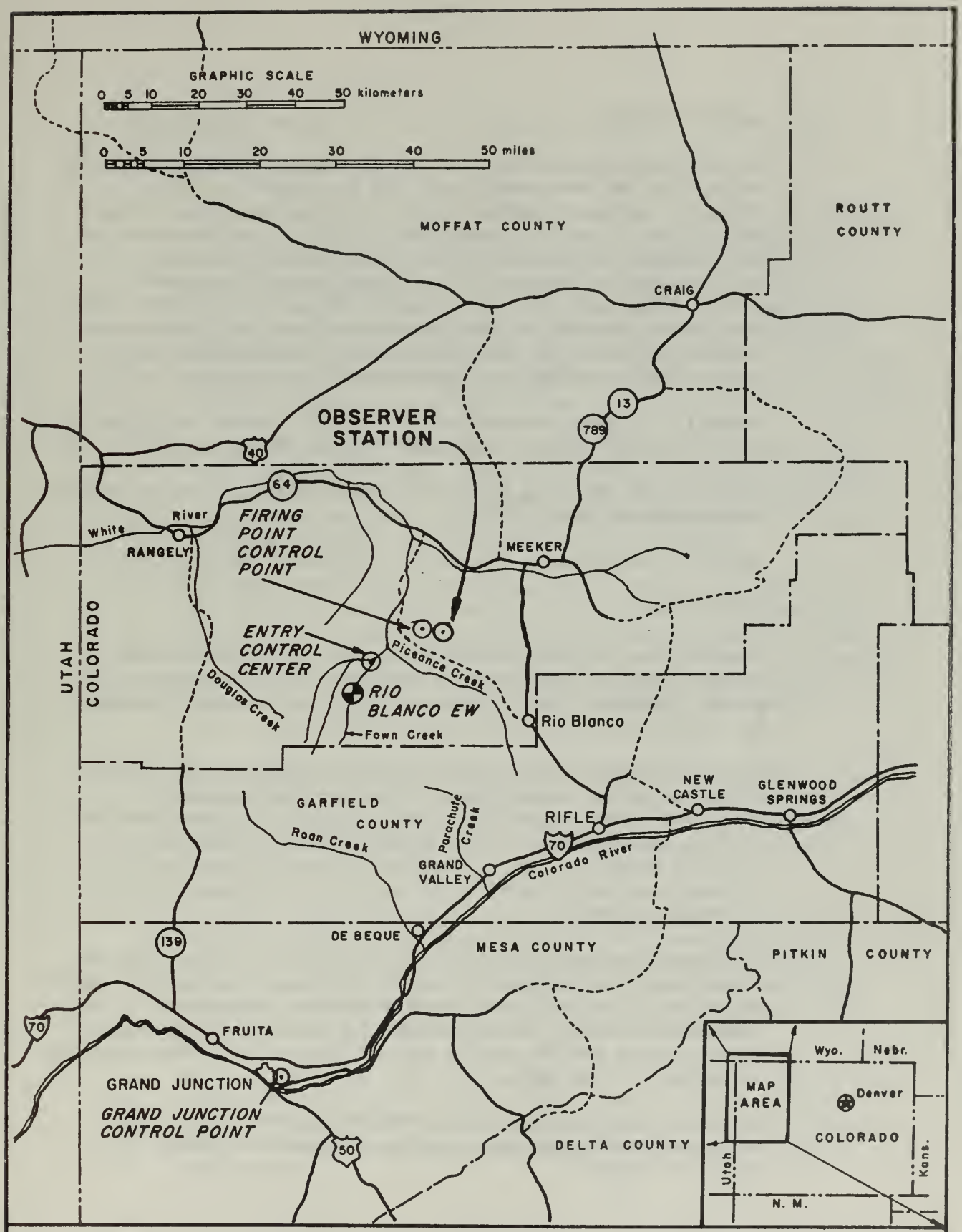


FIGURE 1-1 AREA MAP SHOWING RELATIONSHIP OF THE RIOBLANCO PROJECT FACILITIES TO NEARBY COMMUNITIES AND GRAND JUNCTION, COLORADO, THE NEAREST MAJOR CITY

1-3 AUTHORIZATIONS

The contract between the U.S. Atomic Energy Commission (AEC), acting for the Government, and CER was signed on April 12, 1973. The contract defined the respective roles and responsibilities of the Government and industrial participants in the project. Authority to enter into the contract was received by the Manager of the USAEC, Nevada Operations Office (NV), from the AEC's General Manager in December, 1972. The General Manager of the AEC reserved certain authorities pertaining to control and detonation of the nuclear explosives. That authority was subsequently delegated to the NV.

Authority to ship the explosives from the Nevada Test Site to the Project Rio Blanco emplacement well: April 26, 1973.

Authority to stem the well after emplacement of nuclear explosives package: May 8, 1973.

Authority to detonate the three explosives: May 14, 1973.

1-4 LITIGATION

The Citizens for Colorado's Future, et al., filed a suit against the Colorado Water Pollution Control Commission, CER, et al. (District Court, City and County of Denver, Colorado, No. C-36127).

The plaintiffs did not seek a judicial ruling on the safety or desirability of the blast. Instead, their arguments addressed rather technical questions of state administrative law: it was claimed that the Commission had conducted no adequate investigation as required by the statute, and that it made inadequate findings to support the issuance of the Rio Blanco permit.

The Honorable Henry E. Santo ruled on May 10, 1973, that the State Court had jurisdiction of both persons and subject matter in the suit and that such jurisdiction was not voided by the "federal preemption doctrine." On May 14, 1973, Judge Santo ruled against the plaintiffs and in favor of all defendants on all points of the suit.

CER filed a protective motion for reconsideration of the jurisdictional issue and a notice of appeal to assure its rights of appeal.

II. CHRONOLOGY--Compiled by R. T. Stearns, AEC/NV

2-1 PRECONTRACT

Project Rio Blanco was originally described in the CER report, "Project Rio Blanco, Feasibility Study, Piceance Basin, Colorado," dated April 16, 1970. This study, prepared for the Equity Oil Company, evaluated the prospects for nuclear stimulation of natural gas production on Equity's properties in the Piceance Basin. In the report, 94 sections of Equity Oil Company's land were found to contain from 40 to 100 billion standard cubic feet (BSCF) of gas per section in a 1,500- to 2,000-foot zone of the Fort Union and upper Mesaverde formations.

Equity Oil Company evaluated the prospects contained in CER's Draft Feasibility Study and agreed that the northern portion of the Piceance Basin was amenable to nuclear stimulation. A joint venture agreement to carry out the project was signed on March 24, 1970, by CER and Equity Oil Company.

The CER Project Rio Blanco Feasibility Study recommended the testing of several gas bearing sand lenses in the Fort Union and Mesaverde formations to determine their potential. Two wells, Fawn Creek Government Number 1 and Scandard Draw Number 1, were selected for recompletion, testing, and logging between April and December, 1970, to obtain detailed information on the reservoir characteristics.

Surface studies were made of sand outcrops to determine the orientation and extent of sand lenses in the Fort Union and Mesaverde formations. Seismic surveys were also conducted to determine the location of any geologic faults in the area of interest.

A formal project proposal and the Feasibility Study were forwarded to the AEC on May 8, 1970, for consideration as a next step in the AEC's Plowshare program for the nuclear stimulation of natural gas production. A project definition contract was signed December 18, 1970, after the Government had reviewed the feasibility of Project Rio Blanco.

In January, 1971, the Lawrence Livermore Laboratory (LLL) was selected by the AEC to supply the nuclear explosives and associated services for the project. The NV was designated as the contracting and operations office to implement Project Rio Blanco.

Based upon the information developed and subsequently consolidated in the Rio Blanco Reservoir Report, the Fawn Creek site was selected as the stimulation site.

A comprehensive structure inventory, conducted out to a radius of 30 miles from the emplacement well, was completed on June 15, 1971. Drilling of the Rio Blanco emplacement well commenced on September 28, 1971, and was completed April 23, 1972.

Land Use Permits from the Bureau of Land Management were applied for during September and October, 1971, requesting temporary use of acreage for the conduct of the experiment.

The Project Rio Blanco Definition Plan was published and issued March 3, 1972, and associated documents were issued as they were completed. Among these were the Project Rio Blanco Environmental Impact Evaluation (October 12, 1971), Project Rio Blanco Demonstration Program (January 20, 1972), Geology of the Piceance Basin, Revision 1 (December 2, 1971), Hydrology of the Piceance Basin (July 30, 1971), and the LLL Technical Studies (August 2, 1971).

A Draft Environmental Statement for Project Rio Blanco was prepared by the AEC and published in accordance with the National Environmental Policy Act of 1969 and guidelines of the Council on Environmental Quality in January, 1972. Public hearings were conducted in Meeker, Colorado, on March 24, and in Denver on March 27-28. The final statement was published in April, 1972. An Addendum to the Environmental Statement was published March 12, 1973, to bring consideration of project environmental factors up to date.

NV reviewed CER's Project Definition Plans and forwarded them to the Headquarters with an analysis and recommendation for proceeding with the project in early June, 1972. The NV Containment Evaluation Panel categorized Project Rio Blanco as a Category I test on August 25, 1972.

In December, 1972, Headquarters, AEC, authorized the Manager, NV, to enter into negotiations with CER for a contract to execute Project Rio Blanco.

Negotiations for the execution contract commenced on December 13, 1972, with the resulting contract signed on April 12, 1973.

A final Project Definition Plan revised to reflect changes resulting from the negotiations was published on January 24, 1973.

NV forwarded a request for Detonation Authority for Project Rio Blanco to the Headquarters on February 27, 1973.

The drill rig for the emplacement of the three nuclear explosives was moved onsite and rigged up on March 14, 1973.

2-2 POSTCONTRACT

BLM Land Use Permits were issued April 12, 1973. During April, 1973, AEC and LLL personnel began to arrive for the detonation phase of the project. The three nuclear explosives arrived on May 2, 1973, and the emplacement operation began on May 3.

The major structural bracing effort was completed on May 12, 1973.

Stemming commenced on May 9 and was completed on May 10, 1973, and detonation authority was received on May 14, 1973. Detonation of the three explosives occurred on May 17, 1973.

III. LAWRENCE LIVERMORE LABORATORY TECHNICAL MEASUREMENTS PROGRAMS--
Compiled by J. Toman, LLL

3-1 GROUND SPALL MEASUREMENTS

The purpose of the spall* measurements program was to determine with dynamic instrumentation the extent of tensile failure of the earth materials caused by the reflection as a rarefaction of outgoing stress waves at the ground surface. The primary reason for the measurement was the concern raised by some that the explosion would fracture the overlying oil shale deposits and increase mining costs. Although oil shale exists from depths of about 400 feet to 2,300 feet at the project site, the Mahogany Zone at an approximate depth of 750 to 900 feet is of primary interest because it contains the highest grade oil shale.

The extent of spall has been determined by a preliminary examination of the data from 20 accelerometers and 16 velocity gauges. Although a detailed analysis is still underway, the spalled zone can be described as a shallow dish with a depth of less than 350 feet and a radius of less than 24,000 feet. Therefore, no spall has occurred in the oil shale deposits. Table III-1 summarizes the instrument locations, the time of arrival of the incident compressive wave, an indication of whether or not spall characteristics are visible in the data, the peak incident acceleration in g's, and the peak velocity in feet per second.

Figure III-1 compares the accelerations recorded at 12,000 and 24,000 feet from the EW. These instruments were placed at a depth of about 15 feet. Spall is clearly visible where an acceleration of -1g occurs during the period from 165-305 milliseconds at the 12,000 foot station (the time in this plot has not been correlated with the time of the detonation). The 24,000-foot station shows only free field characteristics and, therefore, no spalling has occurred. The results obtained to date are in excellent agreement with the predetonation predictions presented in UCID-16078, "Spall Measurements Program for Rio Blanco" by J. Toman, R. Terhune, and C. Sisemore, dated July, 1972. Any significant changes in the permeability of the formation where spall has occurred should be observable in the on-going hydrologic testing.

3-2 CLOSE-IN ACCELERATION MONITORING

The vertical component of motions to which the wellhead was subjected were measured by three accelerometers fastened to the wellhead. Data from only one instrument have been analyzed and interpreted as follows:

*The temporary separation of rock layers under tension.

TABLE III-1

Spall Instrumentation Locations and Recorded Data

Instrument Package #	Horizontal Range (ft)	Depth (ft)	Slant Range (ft)	Time of Arrival (msec)	Spall	Peak Acceleration (g's)	Peak Velocity (ft/sec)
01 Ac80V	148.26	61	6,170	527.45	Yes	9.5	3.1
01 Ac150V		149	6,082	516.8	Yes	8.2	2.0
02 Ac350V		352	5,879	492.7	No	9.0	1.7
02 Ac450V	128.43	452	5,779	482.9	No	10.0	1.6
02 Ac600V		604	5,627	470.4	No	8.5	1.2
03 Ac720V	130.48	723	5,508	459.7	No	11.51	1.8
03 Ac820V		821	5,410	448.5	No	13.0	2.0
04 Ac120V	2,435	120	6,610	554	Yes	4.2	1.5
05 Ac280V	2,413	285	6,449	537	Yes	4.0	0.85
05 Ac380V		398	6,344	526	No	3.2	1.0
06 Ac90V	7,248	107	9,560	778	Yes	1.8	1.6
06 Ac190V		190	9,506	767	No	1.2	1.0
06 Ac290V		288	9,443	760	No	1.4	0.7
06 Ac550V		532	9,288	741	No	1.9	0.75
06 Ac630V		630	9,227	732	No	2.2	0.75
000 Ac00V	138.23	15	6,216	542	Yes	2.9	-
2600S	2,420	35	6,683	570	Yes	4.6	2.3
7300	7,200	15	9,516	806	Yes	1.7	-
12000	12,034	15	13,450		Yes	1.8	-
24000		15			No	0.6	-

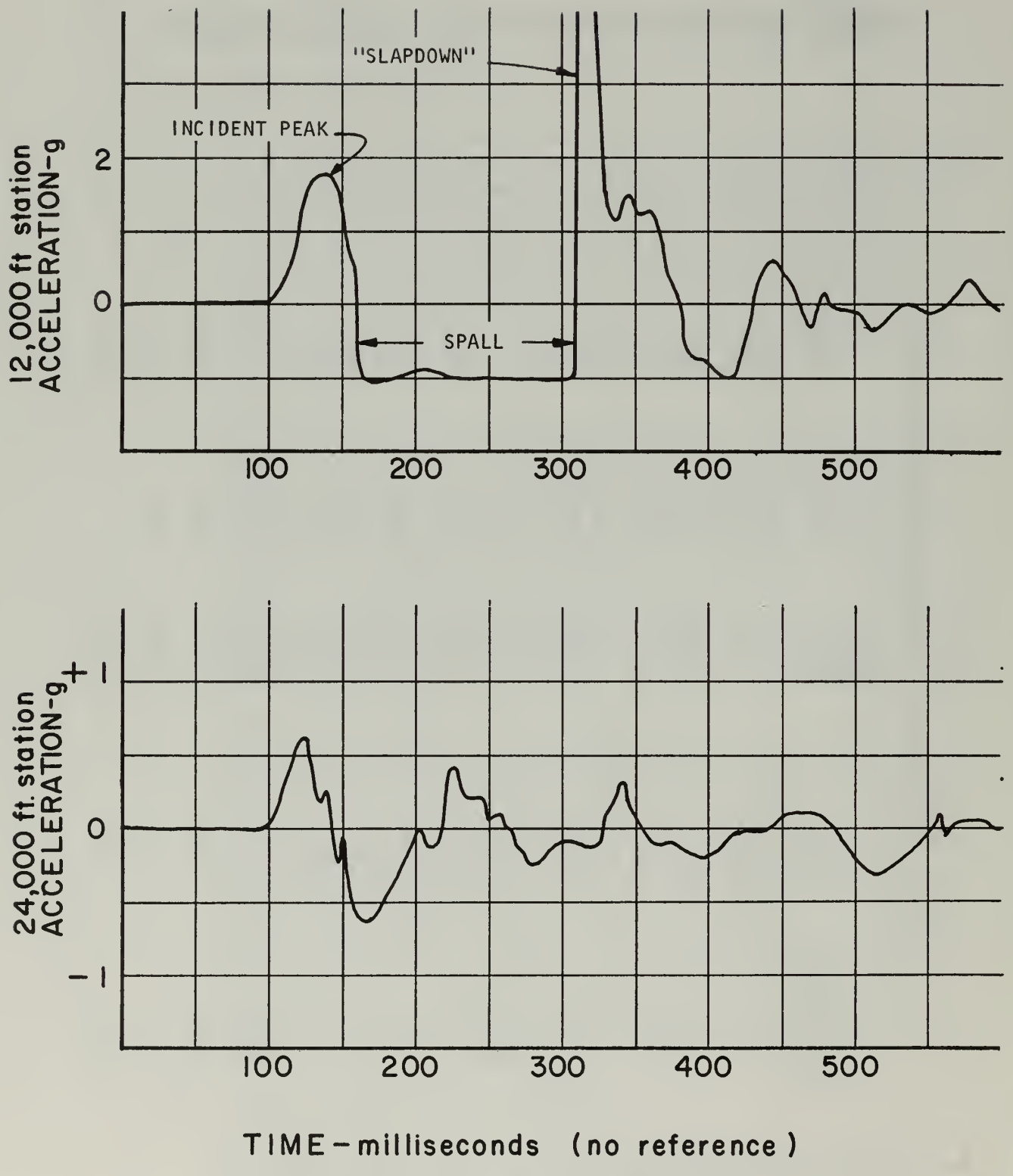


FIGURE III-1 INSTRUMENT DEPTHS ~15 FEET BELOW GROUNDSURFACE

Peak Acceleration	32.5 g's
Peak Velocity	3.25 ft/sec
Peak Displacement	2.0 inches

3-3 CHIMNEY GROWTH AND FRACTURE HEIGHT MEASUREMENTS

The two coaxial cables which were installed in the EW were electrically measured postdetonation to establish their physical lengths. A standard unarmored RF-1 cable which is identified as the Detonation Verification Cable was pulsed starting at less than 50 milliseconds postdetonation in an attempt to measure chimney growth. This cable had already been broken by this time at a point 335±5 feet above the top explosive. This measurement implies chimney top at about 5,500 feet. The firing cable, a specially built high temperature, double-armored cable was broken at 152±5 feet above the top explosive. The longer length of this cable is undoubtedly due to its high tensile strength. These cable lengths were again measured during the week of June 4, 1973, and found to be unchanged. The actual chimney top will be established by reentry drilling.

3-4 CHIMNEY INTERCONNECTION MEASUREMENTS

A different noble gas "tracer" (inert and nonradioactive) was incorporated in each nuclear explosive package. The purpose of these tracers is to determine whether the chimneys from the three explosions are connected. Although samples containing some chimney gas have been obtained through the gas sampling system, these samples are too small to detect the gas tracers. Detection of these tracers and an assessment of the degree of connection between chimneys is part of the postdetonation production testing program.

3-5 GAS SAMPLING AND CHIMNEY PRESSURE MEASUREMENTS

Communication with the chimney was not established immediately postdetonation as originally planned, even though the two diaphragm valves at depths of 3,000 and 4,000 feet in the prompt sample line were ruptured. The gas sampling line was pressurized to 5,000 psi at the wellhead without any real indication of the opening of a flow path to the chimney. Pressures in the sampling tube rose slowly at a rate of about 5 psi per day until the evening of May 31, 1973, when the rate started to increase more rapidly and reached about 150 psi per day. The reason for this behavior is unknown. One speculation is that some additional collapse of the chimney top may have occurred, although no change in the lengths of the cables in the EW has been observed.

Samples of gas from the sampling tube were obtained on June 5, 7, 14, and 27, 1973. Only the June 5 sample has been sufficiently analyzed to date. The radionuclides which have been identified show conclusively that communication with the chimney has been achieved. Results of the analysis of the June 5 sample are compared to calculated chimney gas concentrations as shown in Table III-2, Radioactivity in Sampling Tube Gas vs Predicted Chimney Gas.

TABLE III-2

Radioactivity in Sampling Tube Gas vs Predicted Chimney Gas

	June 5 Sample pCi/ml	Expected Chimney Gas @ 19 Days pCi/ml	Expected Chimney Gas @ 6 Months pCi/ml
Krypton-85	70	240	240
Xenon-133	3,000	270,000	-
Argon-37	300	<7,500	<310
HT (tritiated hydrogen)	2		
CH_3T (tritiated methane)	0.3	<19	<19
Radon-222	(0.02	natural radioactivity)	

In general, the radioactivity measured is lower than expected and may be the result of dilution with fresh formation gas from sand lenses at or above the top of the chimney. The short-lived radionuclides such as Xenon-133 and Argon-37 must be compared to their calculated concentrations at 19 days post-detonation. The Krypton-85 concentration is about 1/3 of that expected for chimney gas, but the Xenon-133 concentration is so much smaller that some other mechanism must be selectively eliminating this radionuclide.

The chemical composition of the gas sample does not agree with the predicted chimney gas composition either. A comparison of key constituents is shown in Table III-3.

TABLE III-3

Chemistry of Sampling Tube
Gas vs Predicted Chimney Gas

	June 5 Sample Volume %	Estimated Chimney Gas Volume %	Measured Ft. Union Gas Volume %
H_2	1.33	15	.06
CO_2	0.12	30	0.6
CH_4 (methane)	94.8	50	94

The predominant feature of the chemical composition is the virtual absence of CO_2 in the June 5 gas sample. It can be speculated that the gas sample is being scrubbed by fluids in the sampling tube. However, no firm conclusions regarding the chimney gas quality will be possible until the chimney is re-entered in August or early September or better connection with the chimney is established through the sampling tube.

The pressure in the sampling tube reached a plateau of about 1,600 psi. From this pressure it is possible to infer a chimney pressure of about 1,750 psi assuming the chimney top to be at about 5,500 feet and the gas gravity to be 0.65. The sampling tube was pressurized to 4,000 psi with nitrogen on June 28, 1973, and the pressure drop observed. This test results in an inferred chimney pressure of about 1,800 psi. It is believed that measurement of the chimney pressure will be one of the more successful aspects of the gas sampling and chimney pressure measurements program. A pressure history of the gas sampling tube is shown in Figure III-2.

3-6 DETONATION VERIFICATION MEASUREMENTS

As shown in Figure III-3, electromagnetic pulses induced in a standard RF-1 cable show the detonation of all three explosives with the planned 10 microseconds delay between each. Figure III-4 is further verification of the detonation of all three explosives in that it shows the incident peak from each of the three explosives on the acceleration trace recorded by instrument package number 02Ac600V of the spall measurements program. This instrument was located almost directly above the explosives at a depth of 604 feet from the ground surface (see Table III-1).

3-7 TECHNICAL PHOTOGRAPHY

Standard color motion pictures and sequence pictures of the EW area at the time of the detonation were taken from a ground station about 500 feet away. The value of this photographic

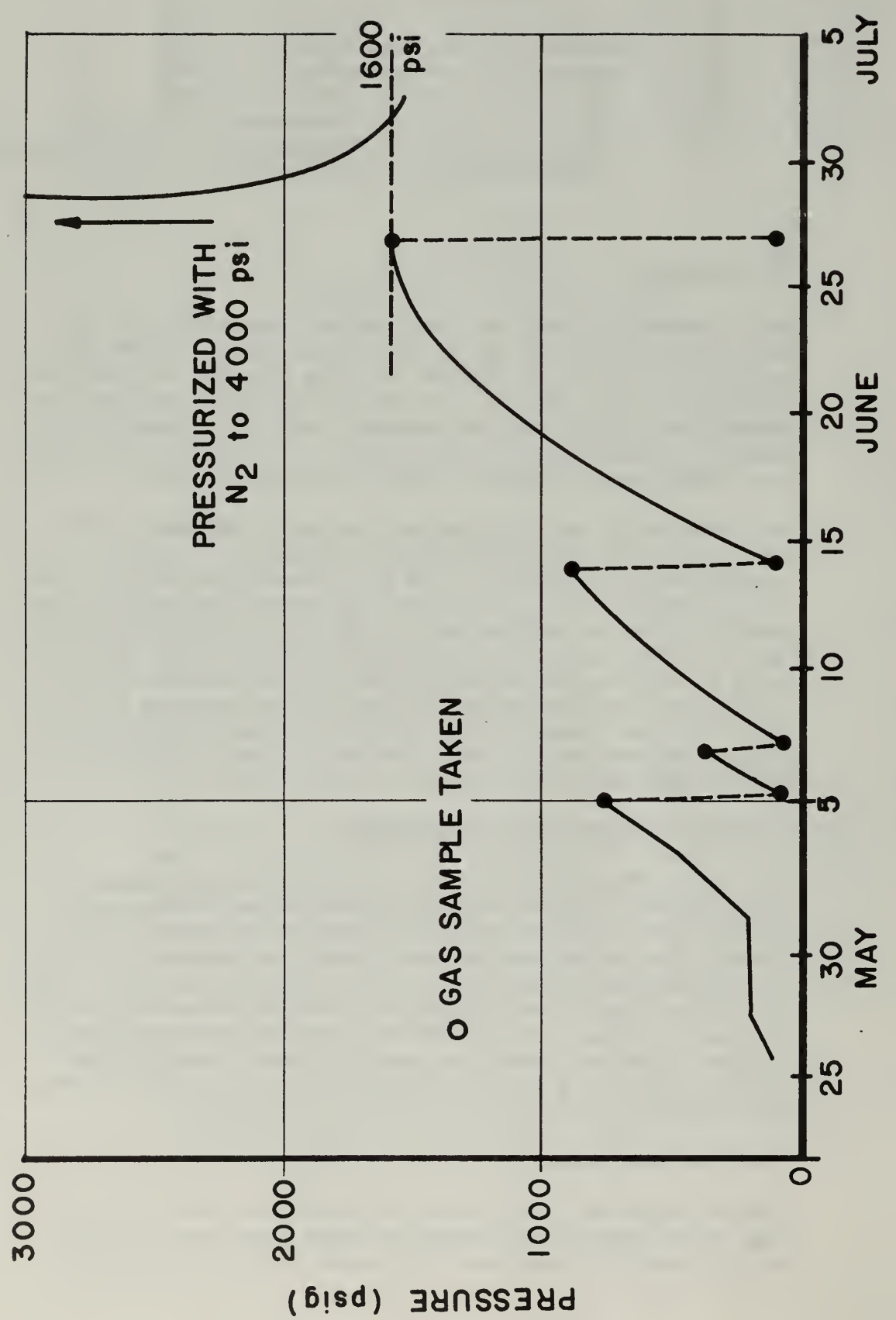


FIGURE III-2 RIO BLANCO GAS SAMPLE TUBE TOP HOLE PRESSURE

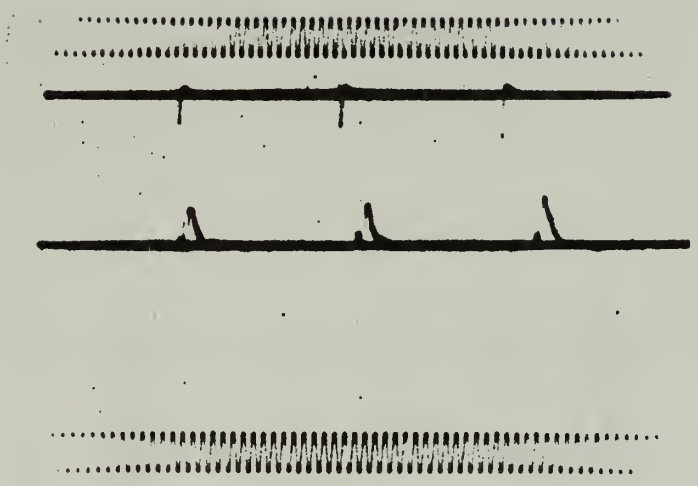


FIGURE III-3
EM PULSER GENERATED BY THREE RIO BLANCO EXPLOSIONS
TIMING WAVE 2 MHz
UPPER TRACE SENSITIVITY 50V/cm
LOWER TRACE 10V/cm

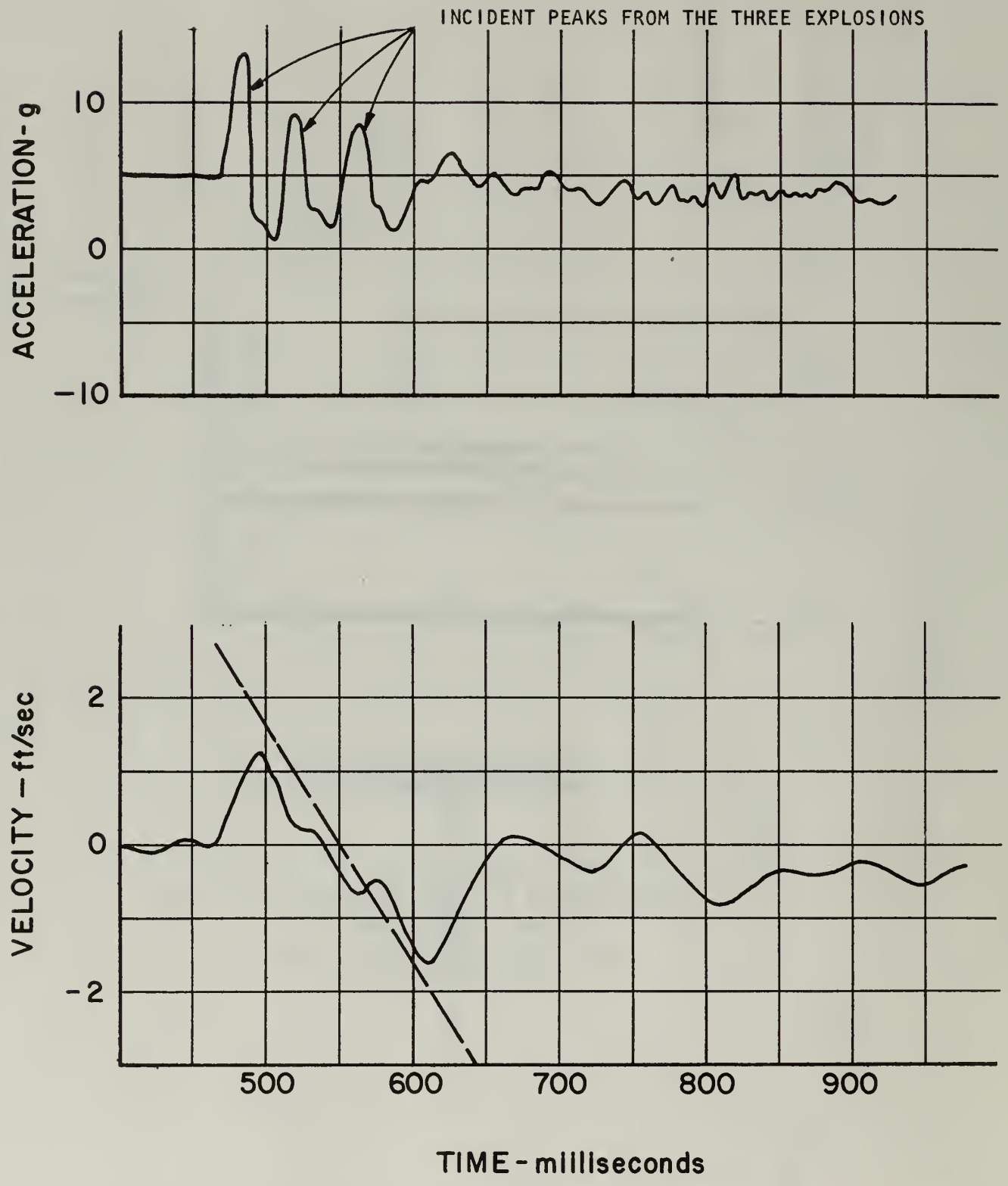


FIGURE III-4 (INSTRUMENT PACKAGE #02Ac 600V - DEPTH OF 600 FEET AT THE EW)

coverage is that it documents a rather negative occurrence--nothing unexpected occurs and after the dust settles no changes can be seen at the wellhead. A small tree growing in the crevice of the rock outcrop near the EW can be seen to topple as the rock falls. Color motion pictures and still photography were used to document the site reentry and wellhead examination. The aerial photography of the site taken from a helicopter was processed and released to the news media on D-day.

IV. EFFECTS PROGRAMS--Compiled by B. G. DiBona, AEC/NV, and R. S. Brundage, CER

4-1 GROUND MOTION

4-1-1 Instrumentation

Thirty-five locations were instrumented for ground motion documentation with L-7 velocity systems by the U.S. Geological Survey/Seismic Engineering Branch (USGS/SEB), formerly the Earth Sciences Laboratory of the National Oceanic and Atmospheric Administration: eighteen were instrumented for CER's basic documentation program; five were instrumented for the structural response studies conducted by Kenneth Medearis & Associates (KMA) (see Add-On Programs); ten were installed in five close-in communities for a ground motion-structural response correlation study conducted by John A. Blume & Associates, Engineers (JABAE) (see Add-On Programs); further, two were deployed at the Colony Tower and the base of Douglas Pass for the AEC and the USGS/SEB programs, respectively. The locations of these instruments are shown in Figure IV-1.

In addition to the L-7 systems deployed for the detonation, other seismic monitoring equipment was installed for add-on programs conducted by the U.S. Bureau of Mines (USBM), Atlantic-Richfield Company (ARCO), El Paso Natural Gas (EPNG), CER, KMA, Superior Oil Company (Superior), and Engdahl & Associates (E&A) (see Add-On Programs).

4-1-2 Data

The information presented in this report, and particularly the scientific measurements, is considered to be preliminary. Detailed technical reporting of individual project studies will be made available at later times in professional journals and participating organization reports.

The L-7 data have been processed on paper records and scaled for peak velocities on each component and the period of the peak cycle. The data is presented in Table IV-1.

The surface classifications listed in this table are inferred from microtremor surveys where available and visual geologic observations. Where a station is listed as hard rock, the instruments were visibly on hard rock

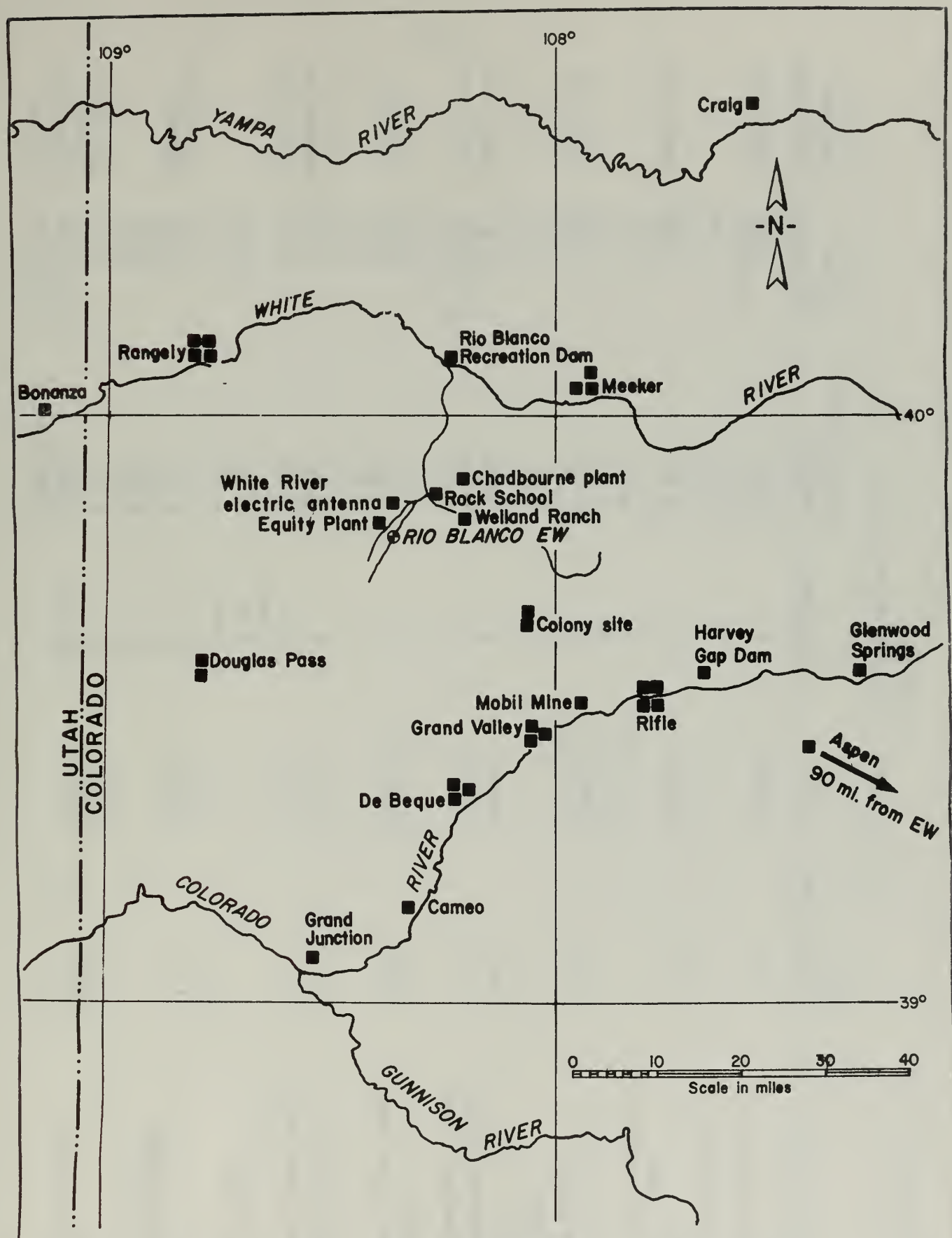


FIGURE IV-1 LOCATION OF L-7 SEISMIC STATIONS, PROJECT RIO BLANCO

TABLE IV-1
All Rio Blanco Stations--Ground Level.

Station	Slant Distance (km)	Level	Component	Peak Velocity (cm/sec)	Period (Sec.)	Surface Conditions
RB-1 (Equity Plant)	6.0	Ground	Z	51.5?	0.15	Hard Rock
			T	26.8	0.17/0.20	
			R	32.3	0.20	
RB-2 (White River Electric Antenna)	7.7	Ground	Z	17.9	0.095	Hard Rock
			W	16.0	0.10	
			S	11.8	0.11	
RB-3 (Rock School Residence)	11.3	Ground	Z	5.10	0.085	Hard Rock
			T	4.65	0.095	
			L	4.04	0.10	
RB-5 (Chadbourne Plant depropanizer tower)	18.9	Ground	Z	7.43	0.2	Hard Rock
			T	2.84	0.10	
			R	4.25	0.10/0.12	
RB-7 (Colony Site Tower)	29.0	Free Field	Z	5.29	0.19	Alluvium
			L	4.19	0.23	
			T	5.55	0.23	
RB-7a (Colony Site Mine)	29.0	Ground	Z	1.26	0.17	Subsurface
			L to tower	0.824	0.22	
			T to tower	0.885	0.22	
RB-8 (Weiland Ranch)	19.1	Ground	Z	4.03	0.19	Unknown
			T	5.37	0.17	
			R	8.53	0.16	
RB-9 (Rio Blanco Rec. Dam)	35.9	Ground	Z	1.56	0.12	Unknown
			T	1.34	0.24	
			R	1.28	0.28	

Table IV-1, Cont.

Station	Slant Distance (km)	Level	Component	Peak Velocity (cm/sec)	Period (Sec.)	Surface Conditions
RB-10 (Douglas Pass, FAA Warehouse)	43.4	Ground	Z	0.562	0.17	Hard Rock
			T	0.592	0.13	
			R	0.513	0.18	
RB-11 (Mobil Mine)	45.7	Ground	Z	0.299	0.23	Subsurface
			T	0.245	0.52	
			R	0.335	0.20	
*RB-12 (Grand Valley)	46.4	Ground	Z	0.256	0.22	Hard Rock
			T	0.330	0.3	
			R	0.572	0.21	
*RB-13 (Meeker)	46.7	Ground	Z	0.436	0.21	Hard Rock
			T	0.166	0.15	
			R	0.597	0.18	
*RB-14 (Rangely, J. L. Supply)	48.9	Ground	Z	0.268	0.15/0.42	Hard Rock
			T	0.271	0.11/0.8	
			R	0.402	0.16	
*RB-26 (Rangely College)	47.6	Gym Floor	T	0.357	0.2 /0.6	Unknown
		Gym Floor	L	0.290	0.2	
		Gym Floor	T	0.310	0.6 /0.23	
		Gym Floor	L	0.184	0.2	
*RB-15 (DeBeque School)	53	Ground	Z	0.350	0.22	Hard Rock
			T	0.252	0.13	
			R	0.212	0.14	
*RB-16 (Rifle Church)	58	Ground	Z	0.289	0.30	Hard Rock
			T	0.253	0.24	
			R	0.405	0.15	

*See Figure V-3.

Table IV-1, Cont.

Station	Slant Distance (km)	Level	Component	Peak Velocity (cm/sec)	Period (Sec.)	Surface Conditions
*RB-17 (Rifle, Miller's Car Wash)	57	Ground	Z	0.363	0.22	Unknown
			T	0.238	0.52	
			R	0.445	0.19	
RB-18 (Harvey Gap Dam, Toe)	64	Ground	Z	0.317	0.18	Alluvium
			T	0.491	0.14	
			L	0.682	0.21	
RB-19 (Cameo)	72	Ground	Z	0.192	0.12	Unknown
			T	0.414	0.17	
			R	0.436	0.18	
RB-20 (Bonanza, Utah)	77	Ground	Z	0.139	0.21	Hard Rock
			T	0.0393	0.20	
			R	0.0949	0.21	
RB-21 (Grand Junction)	83	Ground	Z	0.118	0.11	Unknown
			T	0.311	0.22	
			R	0.240	0.20	
RB-22 (Craig)	84	Ground	Z	0.0601	0.2	Unknown
			T	0.136	0.18	
			R	0.138	0.15	
RB-23 (Glenwood Springs)	93	Ground	Z	0.0190	0.3	Hard Rock
			T	0.0546	0.18	
			R	0.0650	0.1 /0.45	
RB-24 (Aspen)	149	Ground	Z	0.114	0.20	Unknown
			T	0.116	0.30	
			R	0.145	0.27	
*NSG-1 (Grand Valley)	46	Ground	Z	0.512	0.15	Unknown
			T	0.533	0.21	
			R	1.018	0.22	

*See Figure V-3.

Table IV-1, Cont.

Station	Slant Distance (km)	Level	Component	Peak Velocity (cm/sec)	Period (Sec.)	Surface Conditions
*NSG-2 (Grand Valley)	46	Ground	Z	0.313	0.22	Unknown
			T	0.257	0.30	
			R	0.434	0.22	
*NSM-1 (Meeker Hospital)	48	Ground	Z	0.586	0.15	Unknown
			T	0.481	0.18	
			R	0.628	0.14	
*NSM-2 (Meeker High School)	48	Ground	Z	0.534	0.12	Unknown
			T	0.566	0.15	
			R	0.835	0.16	
*NSA-1 (Rangely)	50	Ground	Z	0.328	0.3	Unknown
			T	0.280	0.16	
			R	0.404	0.13	
*NSA-2 (Rangely)	49	Ground	Z	0.549	0.12	Unknown
			T	0.683	0.2	
			R	0.992	0.21	
*NSD-1 (DeBeque)	53	Ground	Z	0.243	0.15	Unknown
			T	0.337	0.18	
			R	0.250	0.11	
*NSD-2 (DeBeque)	52	Ground	Z	0.233	0.22	Unknown
			T	0.190	0.13	
			R	0.244	0.11	
*NSR-1 (Rifle)	58	Ground	Z	0.659	0.13	Unknown
			T	0.710	0.26	
			R	0.806	0.28	
*NSR-2 (Rifle)	57	Ground	Z	0.435	0.14	Unknown
			T	0.775	0.40	
			R	0.734	0.27	

*See Figure V-3.

Table IV-1, Cont.

Station	Slant Distance (km)	Level	Component	Peak Velocity (cm/sec)	Period (Sec.)	Surface Conditions
Douglas Pass Base	∿ 43	Ground	Z	0.391	0.15	Unknown
			T	0.446	0.32	
			R	0.473	0.20	

Z--Vertical Component
T--Transverse Component
R--Radial Component
W--West
S--South
L--Longitudinal Orientation to Structure

or the microtremor survey showed a ground resonant frequency of greater than 15 Hz. Where the surface conditions were unknown, the station is so classified. Where the microtremor survey showed a ground resonance of less than 15 Hz or geologic information was available to show the presence of alluvium, the station surface conditions were classified as alluvium.

4-1-3 Analysis

Using the hard rock stations only, CER performed a regression analysis using peak horizontal velocity component data from 6 to 19 km and obtained a regression curve of $U_h = 628\ R^{-1.8}$, where U is peak horizontal component of velocity in km/sec, and R is in kilometers. Data from 19 to 93 km resulted in a regression curve of $U_h = 13127\ R^{-2.67}$. These curves and the observed data are shown in Figure IV-2. The predicted curves developed by CER are:

$$U = 368\ R^{-1.46} \text{ for 6-22 km}$$
$$U = 3549\ R^{-2.17} \text{ for 22-300 km}$$

These predictions were made using a predicted effective yield of 100 kt. The majority of the data fall well below the CER's predicted values and the attenuation rate is greater than predicted. On the average, the observed hard rock data seems to be 50 to 60 percent of the predicted values.

A regression analysis of the stations classified as alluvium or unknown results in a regression curve of $U_h = 4061\ R^{-2.17}$ for 19 to 149 km. A comparison of the regression curve and the observed velocity values is shown in Figure IV-3. The large scatter in the data is probably due to uncertainties in the surface classification. Additional microtremor work would probably reveal that some of the low value stations should be regarded as hard rock which would raise this curve and reduce the scatter considerably.

The two mine stations have not been included in the hard rock or alluvium data analyses. Since the instruments are below the surface, the predictions should be one-half the hard rock surface values. If one doubles the mine values, they appear to be in close agreement with the regression curve.

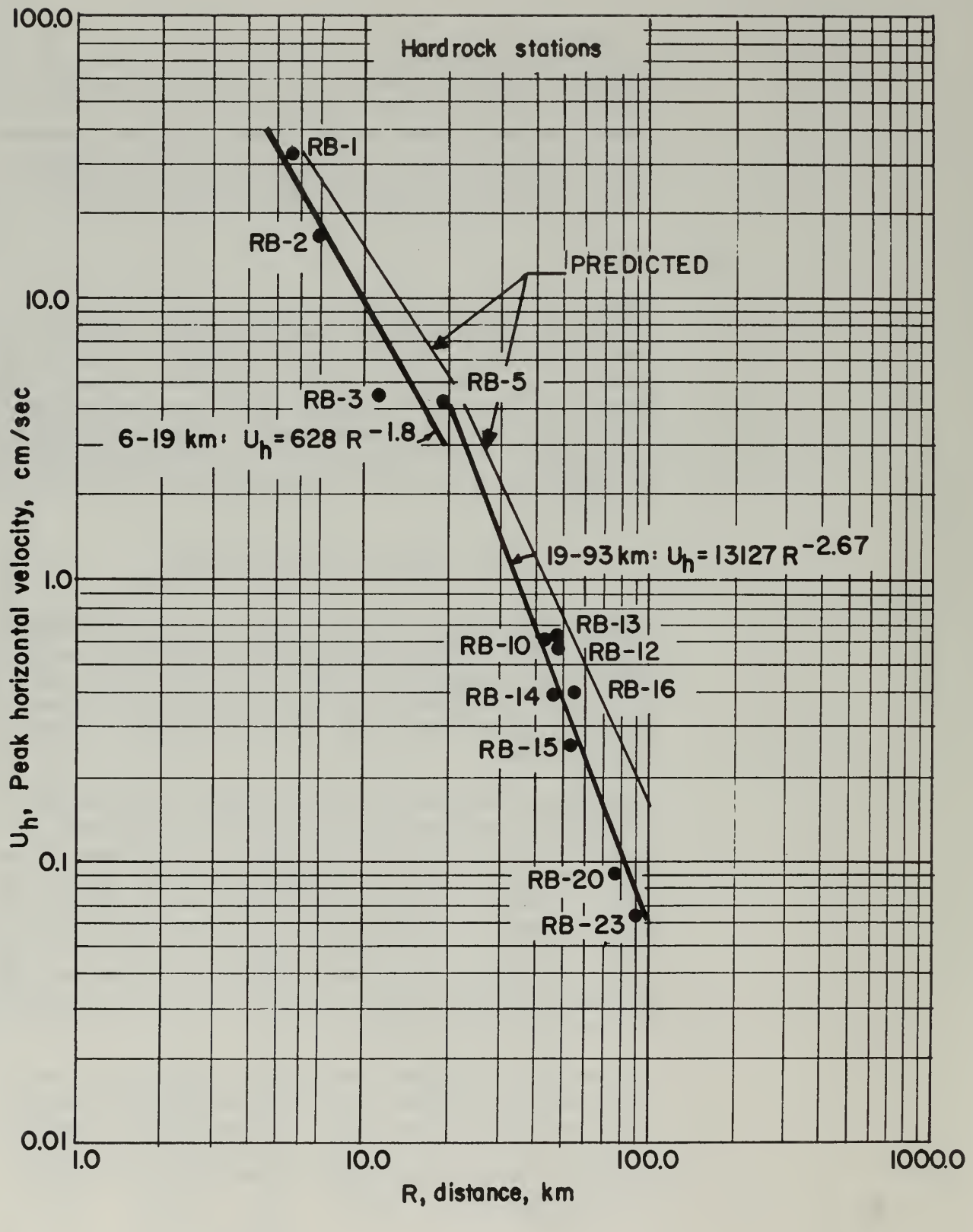


FIGURE IV-2 OBSERVED PEAK HORIZONTAL COMPONENT VELOCITY, PROJECT RIO BLANCO

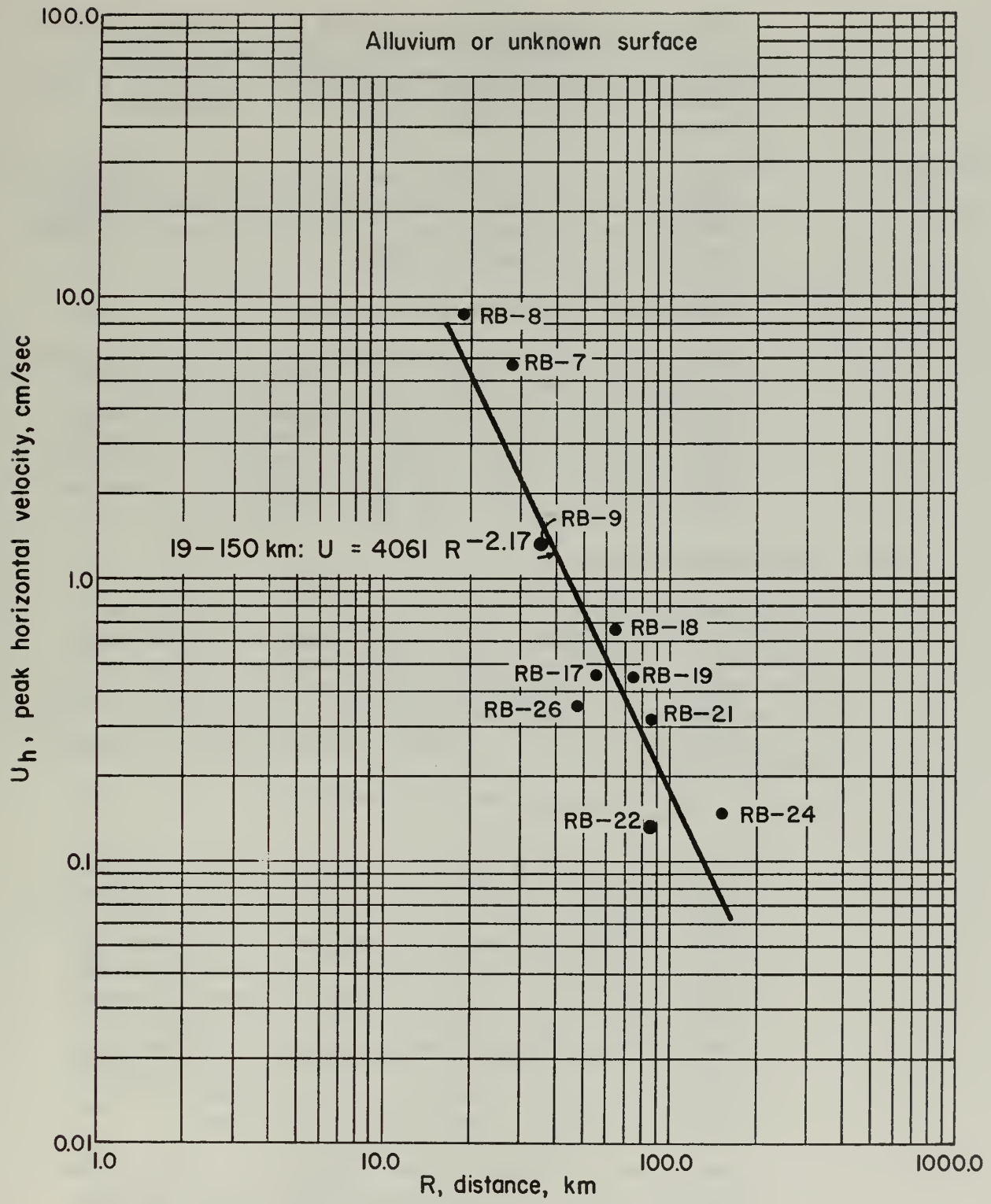


FIGURE IV-3 OBSERVED PEAK HORIZONTAL COMPONENT VELOCITY, PROJECT RIO BLANCO

While the Project Definition Plan does not indicate any further processing of the data, CER plans to obtain values for peak acceleration and PSRV. No effort is contemplated by CER to obtain values for displacement or for vectors.

As indicated in the Environmental Statement, Environmental Research Corporation (ERC) also prepared ground motion predictions for the project. Results of analysis by ERC are not available at this time.

4-1-4 Equivalent Earthquake Magnitudes

Nineteen seismological observatories reported magnitudes for the Rio Blanco detonation. Table IV-2 lists the magnitudes (m_b) reported to the National Earthquake Information Center in Boulder, Colorado. It is interesting to note that these magnitudes range from a low of 4.7 to a high of 6.3. The NOAA/NERC, however, has averaged them and will report a magnitude of m_b 5.4.

4-2 STRUCTURAL RESPONSE

The Project Rio Blanco responsibilities of CER's structural response consultant, KMA, included an inventory of all structures in the project area, structural response predictions, slope stability evaluations, estimates of damage, safety measure recommendations, and the bracing of certain structures. All but the bracing have been covered in three previous KMA Project Rio Blanco reports.

4-2-1 Structural Bracing

It should be noted that the structural bracing program for Project Rio Blanco was fairly extensive. The most time-consuming effort was conducted at the historic Rock School, which was completely regrouted to a depth of about six inches from the outside and heavily braced. Other bracing was installed at the adjacent concrete block school, the Shell Oil Shale Plant, Equity Oil Shale Plant, Bookcliff Bowling Alley, Chadbourne Gas Compressor Plant, El Paso Gas Plant, Rangely College, Harvey Gap Dam spillway, as well as a number of trailers, chimneys, and miscellaneous items.

The detonation ground motion appeared less than ground motion predictions (2.5 times the CER median predictions) used to evaluate seismic damage. In view of the lower level of ground motions, it is somewhat difficult

Table IV-2

Magnitudes Reported by Seismological Observatories for Project Rio Blanco

Station Abbr.	Location	Distance (km)	*Magnitude (m_b)
BMO	Blue Mountains, Oregon	920	6.1
NEW	Newport, Washington	1,164	6.2
TUL	Tulsa, Oklahoma	1,177	5.9
BKS	Byerly (WWSSS), California	1,214	6.3
JCT	Junction City (WWSSS), Texas	1,284	5.8
FFC	Flin Flon, Manitoba	1,715	5.0
FSJ	Fort St. James, British Columbia	2,001	4.9
CPO	Cumberland Plateau, Tennessee	2,043	4.7
FCC	Fort Churchill, Manitoba	2,324	5.0
PMR	Palmer, Alaska	3,640	4.7
FRB	Frobisher, Northwest Territory	3,694	5.8
GIL	Gilmore Creek, Alaska	3,729	5.3
ALE	Alert, Northwest Territory	5,009	5.4
CAR	Caracas (WWSSS), Venezuela	5,176	5.5
KJF	Finland	7,806	5.4
NUR	Nurmijarvi (WWSSS), Finland	8,049	5.6
MOX	Moxa, West Germany	8,360	5.2
CLL	Collmberg, East Germany	8,372	5.3
TSK	Tsukuba, Honshu	9,008	4.9

*Magnitudes as reported to the National Earthquake Information Center (NEIC), Boulder, Colorado.

to evaluate the effects of the bracing. It was visually obvious the bracing at the Equity Oil Shale Plant was instrumental in precluding damage. Attachment bolts, soil anchors, and wood bracing showed the effects of absorbing dynamic forces. There were also minor visual indications at the Rock School. However, the bracing was designed to absorb only the dynamic force in excess of that which the structure could withstand. For example, tank bracing was primarily placed to carry the dynamic force not absorbed by soil-structure friction. Low-level ground motions may not have caused such bracing to come into play, but visual observations would usually not be adequate for assessing the situation except in extreme cases. In retrospect, the only bracing that might have been eliminated was that placed at the Bookcliff Bowling Alley and Harvey Gap Dam spillway. Both were sources of concern primarily because of the investigations made for Project Rulison. The bracing installed was in accordance with the safety factors added to the mean ground motion predictions. As the latter are refined, bracing requirements can, of course, be modified accordingly.

4-2-2 Bridges

Although KMA predicted no damage to bridges in the Project Rio Blanco area, six were selected for documentation by JABAE, the AEC's structural response contractor. The bridges selected for study in this program include:

Steel truss bridge crossing Colorado River at Grand Valley (47 km from EW).

180-foot steel bridge owned by Colorado Highway Department located at White River--Highway 64 crossing (34.74 km from EW).

90-foot steel truss bridge owned by the Rio Blanco County located at White River--Ivo Shults crossing (33.84 km from EW).

69-foot timber bridge owned by the Colorado State Highway Department located at Highway 64 and Smith Gulch (33.95 km from EW).

108-foot concrete bridge owned by Rio Blanco County located at White River--County Road (38.54 km from EW).

80-foot steel bridge owned by Rio Blanco County located at White River--Piceance road crossing (35.64 km from EW).

KMA inspected these bridges carefully before and after the detonation and found no visible evidence of detonation-related damage.

4-2-3 Colony Development Oil Shale Retort Tower

As part of a structure bracing program for Project Rio Blanco, AEC employed the services of JABAE to conduct structure response analyses and to design structural bracing for the 190-foot-tall Colony Development Oil Shale Retort Tower, situated on Parachute Creek near Grand Valley, Colorado. Other Colony Development structures such as office trailers, sheds, etc., were evaluated by the JABAE resident engineer at the tower site and conservative safety measures were instituted prior to the detonation.

The structural analysis was based on the plus one sigma level of ground motion as predicted by ERC for that specific location. A 2-dimensional computer analysis was utilized by JABAE to develop the modified bracing scheme. The general bracing scheme, including sizes of steel members, was developed by JABAE. Fabrication drawings and connection details for all new and existing bracing members were developed in the field by the JABAE resident engineer who was also responsible for inspection.

Installation of bracing on the tower was performed by the Stearns-Roger Company of Denver, Colorado, under contract to CER during the period April 30 to May 14, 1973. The work consisted of fabricating and placing approximately 21 tons of structural steel shapes (134 pieces) and 750 pounds of welding electrode to strengthen the existing tower bracing system.

The site was evacuated at detonation time as a safety measure and all plant personnel moved to a safe location some distance down the canyon from the tower site. Ground motion was strongly perceptible at this location at detonation time.

No damage or indications of adverse effects from seismic motion was observed during an immediate postshot inspection of the tower structure nor at any other facilities at the tower site (except some minor rockfalls observed in the mine). The tower response appears to have been at somewhat lower levels than those used to develop the bracing design.

Minor rockfalls were also observed on the roadway up to the Colony Development guard gate and on the roadway above the tower structure to the mine entrance, but these were readily cleared. Near a waterfall about 800 feet north of the tower, a rock about 1 cubic foot in size was dislodged from the overhanging cliff.

4-2-4 Damage Claims and Adjustments

As of June 15, 1973, 124 claims have been reported by CER. Of this total, 72 have been settled for a total expenditure of $13,425. Thirty-six (36) have been denied or are reported as no further action to be taken. Sixteen (16) were pending. All claims are for real and personal property and are generally of a superficial nature, as predicted. (Use of the term "claim" here is equivalent to the use of the word "complaint" in similar discussion on Project Rulison.

The following Table IV-3 shows the claim distribution:

TABLE IV-3

Property Damage Claims

Project Rio Blanco
(as of June 15, 1973)

Area	Claims	Settled	Amount	NFAC*	Pending
Piceance Creek	14	10	$ 3,350	2	2
Roan Creek	5	2	108	2	1
Meeker (Rural)	6	4	1,642	2	0
Rifle & Silt (Rural)	4	2	1,740	1	1
Grand Junction	17	12	1,075	4	1
Clifton	4	3	320	1	0
Grand Valley	4	2	171	1	1
Meeker	38	21	2,365	9	8
Rangely	6	4	145	2	0
Rifle	8	5	663	3	0
Silt	3	0	0	2	1
Other	15	7	1,846	7	1
	124	72	$13,425	36	16

*NFAC--No Further Action

4-3 AFTERSHOCKS

The USGS/SEB installed six seismic stations, one 0.28 km northwest of the EW and five in a circular array around the EW at distances of 4.87 to 6.1 km. Figure IV-4 is an area map showing the Rio Blanco EW and the locations of the seismic installation. The seismic data were telemetered, via radio, to a central site, where it was recorded along with WWVB timing on photographic film. The purposes of the seismic monitoring were: (1) to observe any effect of the detonation upon the natural seismicity of the area within 5 km of the EW; (2) to accurately determine the hypocenters of the aftershocks; and (3) to compute the magnitude of the aftershocks.

A single component station (SR1) began operation approximately one and one-half years before the Rio Blanco detonation. Its sole purpose was to monitor natural earthquake activity within 40 km of the Rio Blanco EW. The data and time marks, provided by a Sprengnether SP-300 manually synchronized to WWV, were recorded on a Geotech Helicorder.

The SR1 station was converted to radio telemetry on May 1, 1973, and recorded on a Geotech RF-400 Develocorder at a central recording site, along with five additional stations. Timing, provided by WWVB and a Geotech TG-110 timing system, was simultaneously recorded with the seismic data. The central recording site was at the FPCP. Information on each of the seismic stations is given in Table IV-4.

Only one micro-earthquake within 40 km of Rio Blanco SZ was identified in the year and a half before the detonation. Two weeks after the detonation, there had been no seismic events recorded for six days. Therefore, the array was deactivated except for station RBC (SR1) which will remain active for six months. The micro-earthquake had a magnitude of 0.9 M_L, and occurred October 1, 1972, at 2007:40.3 hours GMT, about 13 km from station RBC (SR1).

The aftershocks generated by Rio Blanco were located within a few thousand feet of the explosion cavity. There were relatively few aftershocks, ceasing within eight days after the detonation. Figure IV-5 is a time-frequency plot of the aftershocks for the first three hours. Only events detected by four or more stations were used. The figure shows larger numbers of aftershocks occurring during the periods of 5-25 minutes, 50-75 minutes, and 90-110 minutes after the detonation. The approximate magnitudes of the larger aftershocks ($\geq$1.5) are indicated.

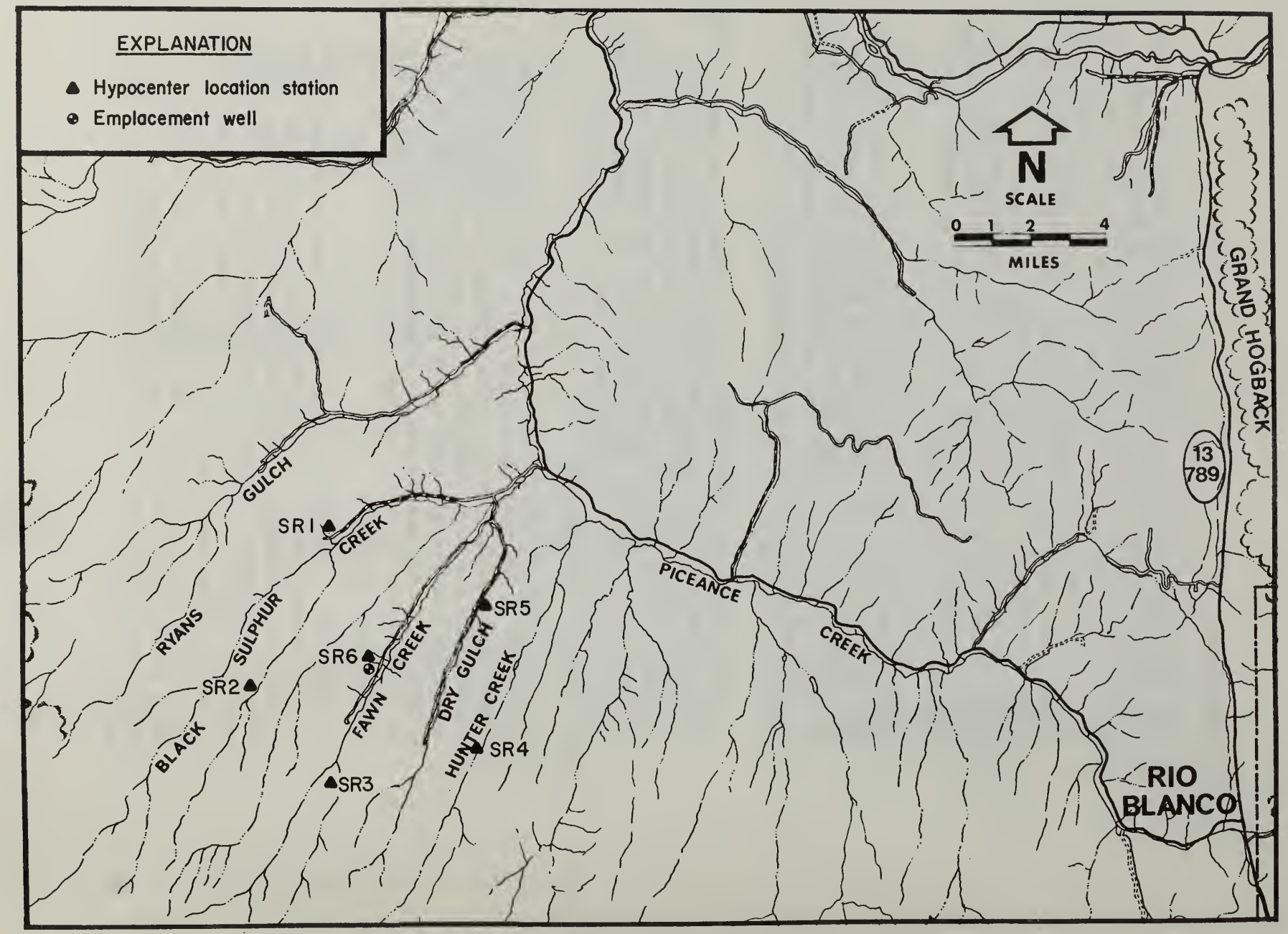


FIGURE IV-4 RIO BLANCO AFTERSHOCK HYPOCENTER LOCATION STATIONS

Table IV-4
Aftershock Hypocenter Location Stations

Station	Dates of Operation	Coordinates	Elevation (Meters)	Distance From EW (km)	System Type	Magnification @ 10 Hz	Remarks
RBC	Nov. 20, 1971 May 1, 1973 June 5, 1973 - Present	39°50'43"N 108°23'34"W	2,005	6.19	L4/6202	4.55×10^5	Also known as SR1
SR1	May 1, 1973 June 5, 1973	39°50'43"N 108°23'34"W	2,005	6.19	L4/6202	1.44×10^5 9.14×10^4	
SR2	May 1, 1973 June 5, 1973	39°47'13"N 108°25'42"W	2,120	5.33	L4/6202	3.20×10^5 7.90×10^4	
SR3	May 1, 1973 June 5, 1973	39°45'05"N 108°23'13"W	2,140	4.95	L4/6202	3.20×10^5 7.06×10^4	
SR4	May 1, 1973 June 5, 1973	39°45'59"N 108°19'10"W	2,138	5.01	L4/6202	3.38×10^5 7.86×10^4	
SR5	May 1, 1973 June 5, 1973	39°49'21"N 108°19'05"W	2,013	5.27	L-7	6.47×10^4	
SR6	May 1, 1973 June 5, 1973	39°47'44"N 108°22'02"W	2,061	0.28	L-7	5.98×10^4 1.49×10^4	

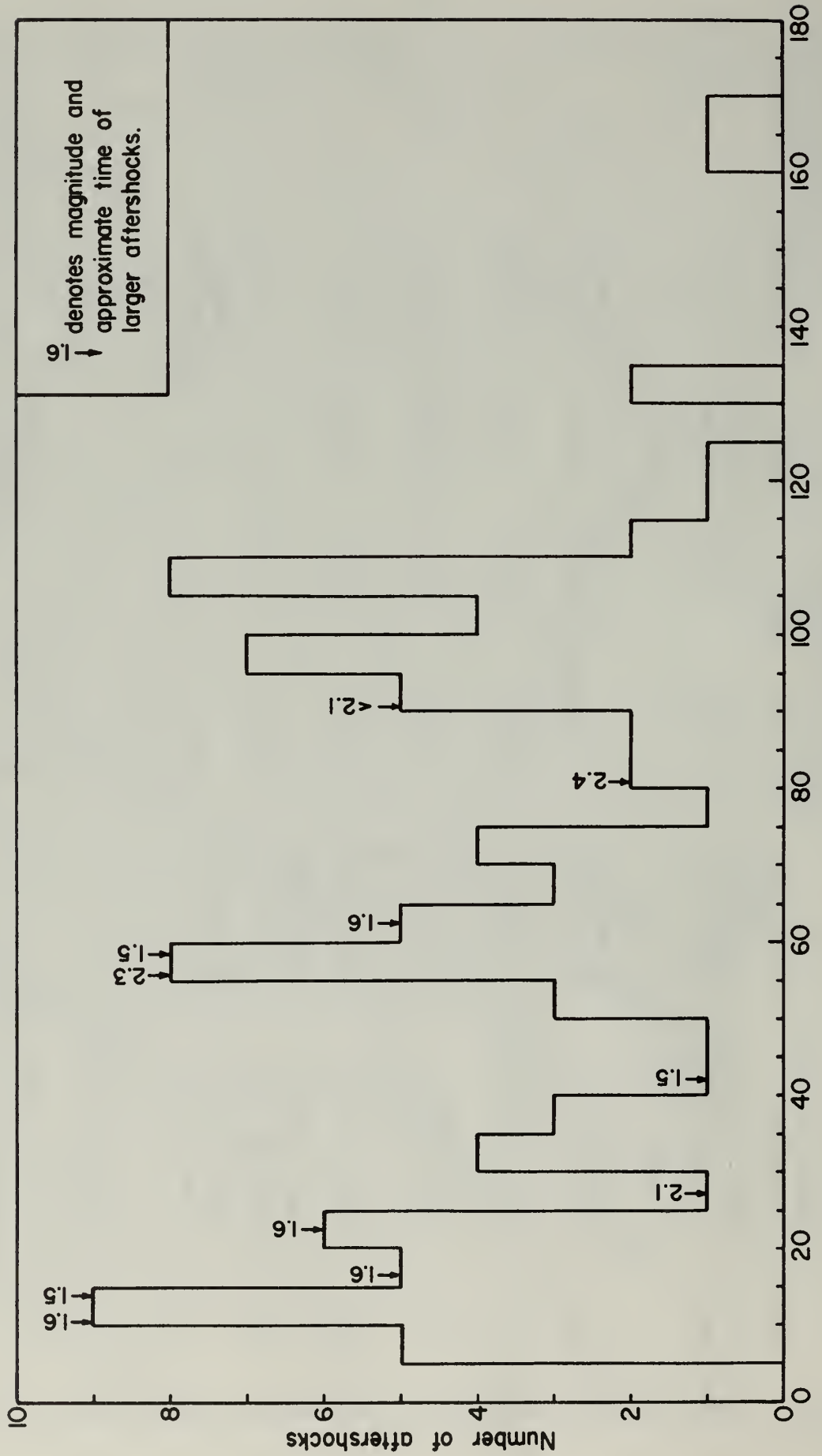


FIGURE IV-5 Number of aftershocks per five minute interval

Figure IV-6 is similar to Figure IV-5, but depicts a longer time after detonation. Note that after the first three hours, the frequency of occurrence has dropped to an average of one aftershock per eight and one-half hours. The last detected event of any significance was on May 25, at 0629 GMT.

The hypocenters of the aftershocks were computed using a computer program having a crustal model of two uniform horizontal layers over a half space. The computed hypocenter location of the Rio Blanco detonation had no horizontal error, but was too shallow by 0.4 km. The data were read to the nearest tenth of a second; the errors in depth and origin time represent errors on the same order and are thus not considered unreasonable. Alternatively, slight errors may exist in the crustal model. Future analysis of the data may resolve the source of the present errors.

The crustal model used is given in Table IV-5.

TABLE IV-5

Crustal Model Aftershock Hypocenter Location Program

Depth (km)	Velocity (km/sec)
0	2.18
0.679	3.21
1.322	4.30

The epicenters have been plotted in Figure IV-7. The small numbers above each symbol represent the number of events which were located at that point. It may be seen that they appear to be grouped in an elongated pattern, trending northwest/southeast. The greatest epicentral distance from the Rio Blanco EW is 0.88 km in a northeasterly direction.

The depth distribution of the hypocenters is shown in Figure IV-8. To the left of the figure are the three Rio Blanco detonation points. The depths were corrected to include the 0.4-km error discussed previously, on the assumption that it represents a systematic error. The shallowest hypocenter was about 0.34 km above the upper explosion and the deepest about 0.12 km below the lowest explosion, a spread of depths of about 0.73 km. Approximately two-thirds of the hypocenters were above the upper explosion, probably indicating most of the activity occurring above or at the top of the explosion cavity.

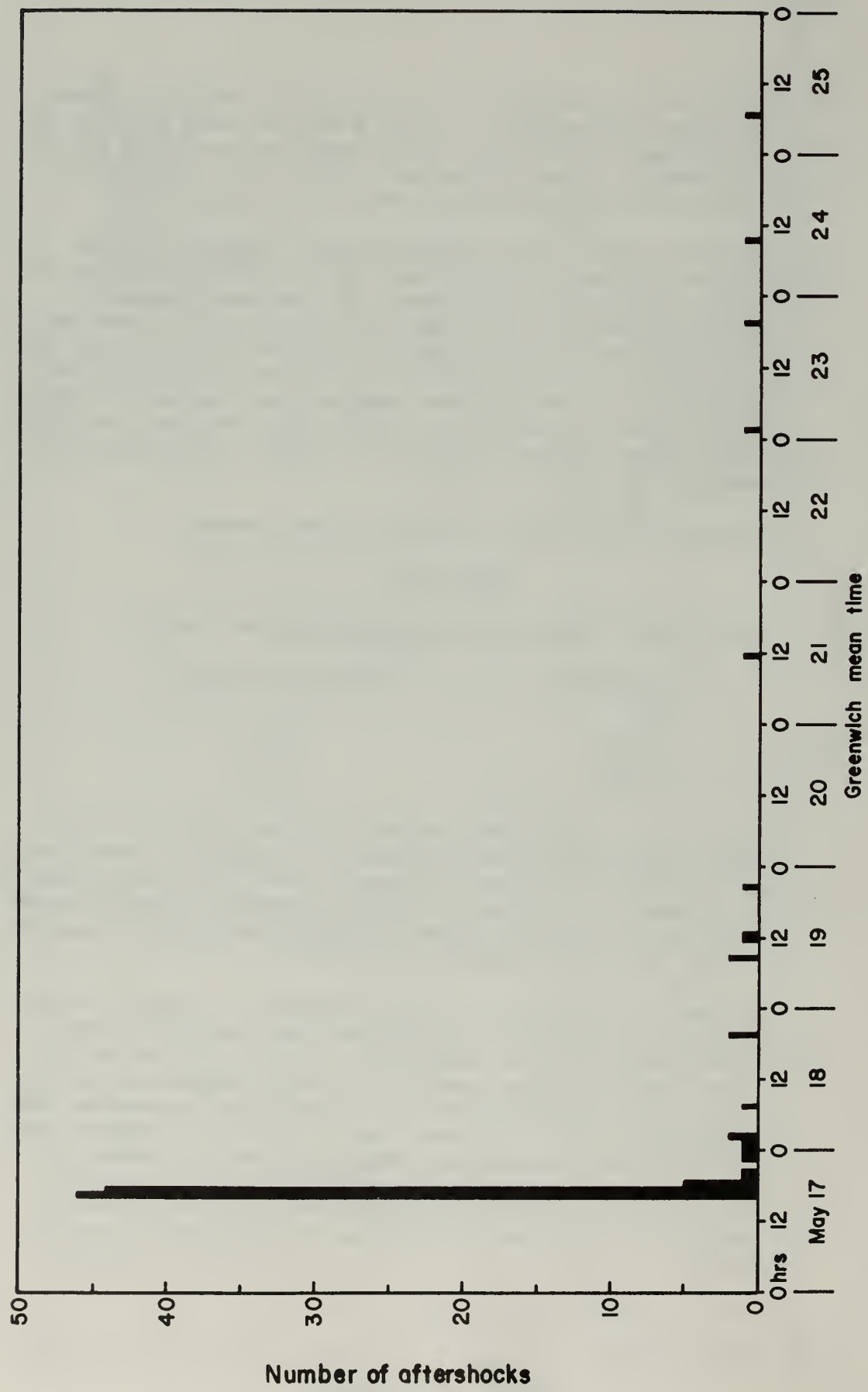
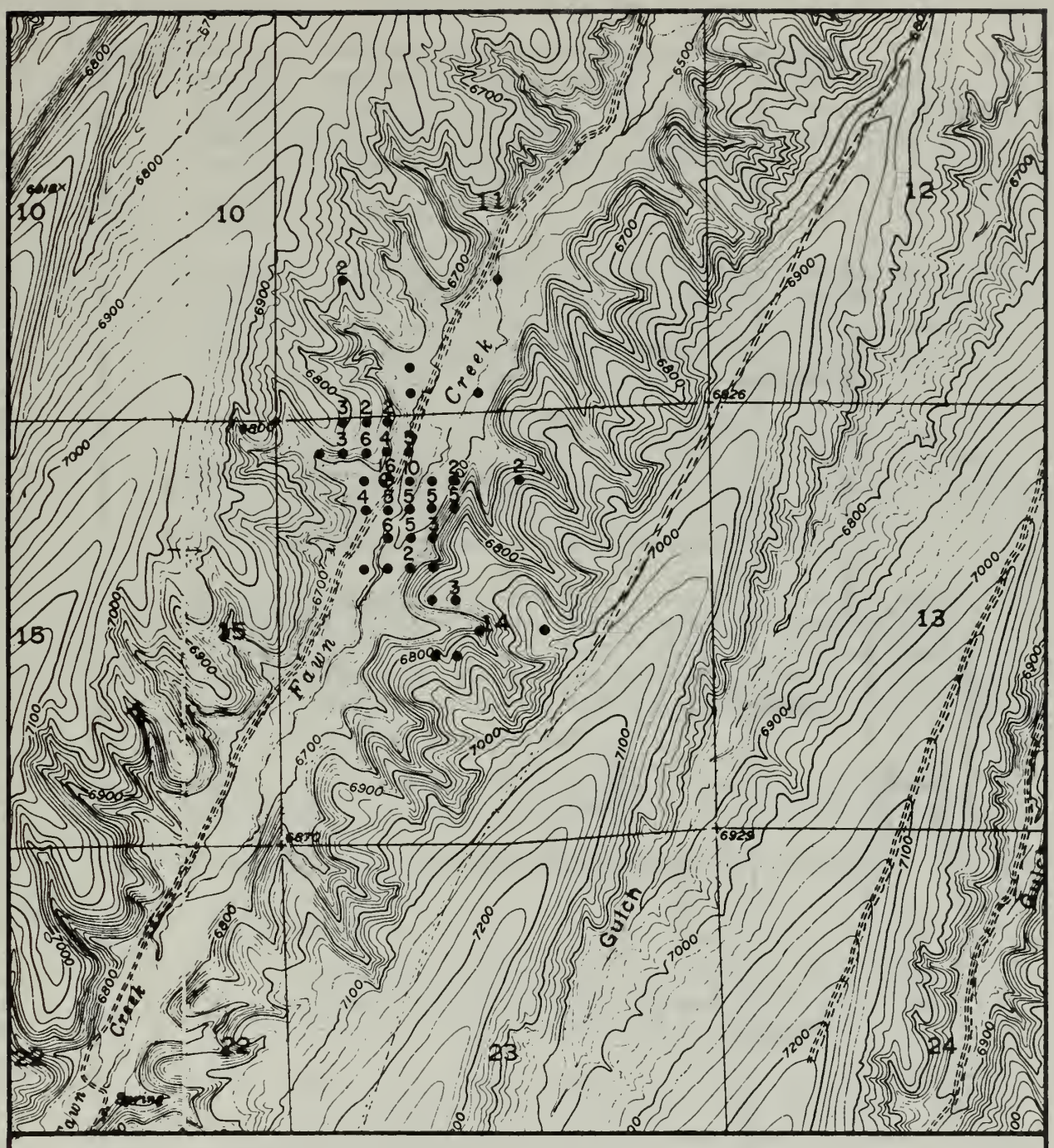


FIGURE IV-6 NUMBER OF AFTERSHOCKS PER ONE HOUR INTERVAL. NO AFTERSHOCK ACTIVITY WAS DETECTED AFTER MAY 25, 1973, AT 0629 GMT.



EXPLANATION

5 Number of aftershocks

Aftershock epicenter

Emplacement well

0 kilometer

0 mile

-N-

FIGURE IV-7 RIO BLANCO AFTERSHOCK LOCATIONS

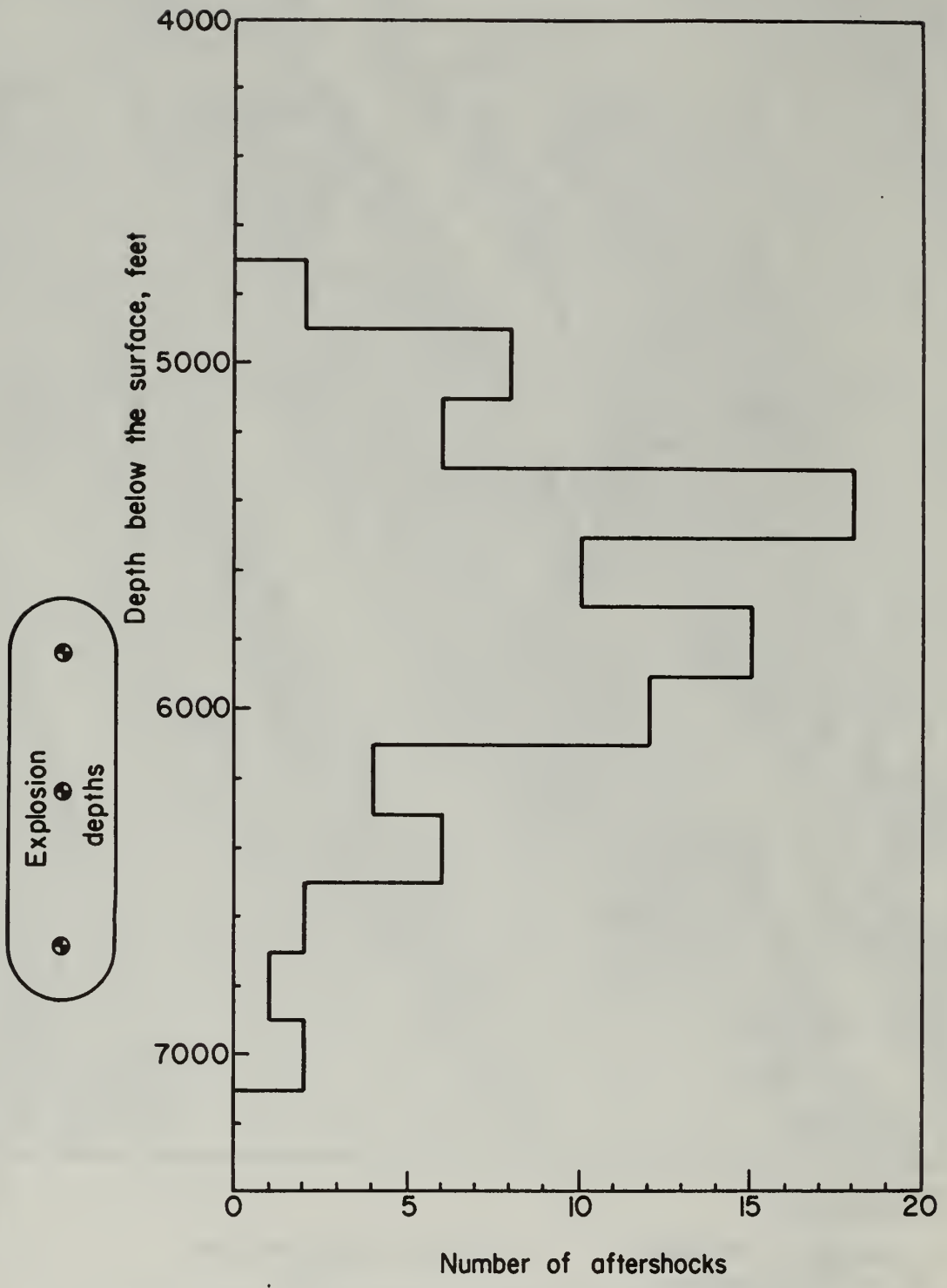


FIGURE IV-8 NUMBER OF AFTERSHOCKS PER 200 FOOT DEPTH INTERVAL. DEPTHS OF THE THREE NUCLEAR EXPLOSIONS ARE SHOWN ON THE LEFT.

The magnitudes of the aftershocks varied, then, from -0.3 to 2.4, with the bulk of them less than 1.0. Ten were greater than or equal to 1.5, with the largest, 2.4, occurring 82 minutes after shot time, at 1722 hours GMT.

4-4 ROCKFALLS ON ROADS

Rockfalls causing road obstructions occurred, but those of any consequence were limited to locations in the Piceance Basin. Rockfalls were reported on nine locations along the Piceance Creek Road, eight along Black Sulphur Creek, eight along Fawn Creek, four on Hunter, and one on East Stuart Creek.

No rocks reached the county road on Parachute Creek; however, small rocks were scattered at four locations between the West Fork Bridge and the Colony Oil Shale site. On Cathedral Creek, three to four rocks dropped on the road and some rocks fell on the Douglas Creek Road just south of Little Horse Draw.

No known rockfalls occurred in DeBeque or Glenwood canyons, the Douglas Pass, or on any of the other state or federal highways, except for a few large boulders on the west-bound lane of Highway 64, about 12 miles west of Meeker. This rockfall occurred within one of the exclusion areas controlled by roadblocks.

Figure IV-9 shows the distribution of the reported rockfall occurrences.

4-5 FAULT STABILITY MEASUREMENTS AND SURFACE CRACK OBSERVATIONS

4-5-1 Faults

The surface rocks north of the EW are cut by several northwest trending down-dropped fault blocks, the nearest trace extending to within 5.5 km of the EW.

Fault traces were visually inspected and photographed at 26 locations before and after the detonation. Seventeen locations were on hardpacked road surfaces and nine on rock and/or alluvial fill. No cracks, scarps, or any other visible evidence of fault motion were observed.

The nine locations on rock and/or alluvial fill were also surveyed as follows: two monuments were established on each side of the fault trace, all initially in a straight line. These monuments consisted of 1.6-cm diameter rebar stakes, 76 cm long, with the upper 15 to 30 cm in concrete. Monument elevations were determined relative to that of the base monument at each location.

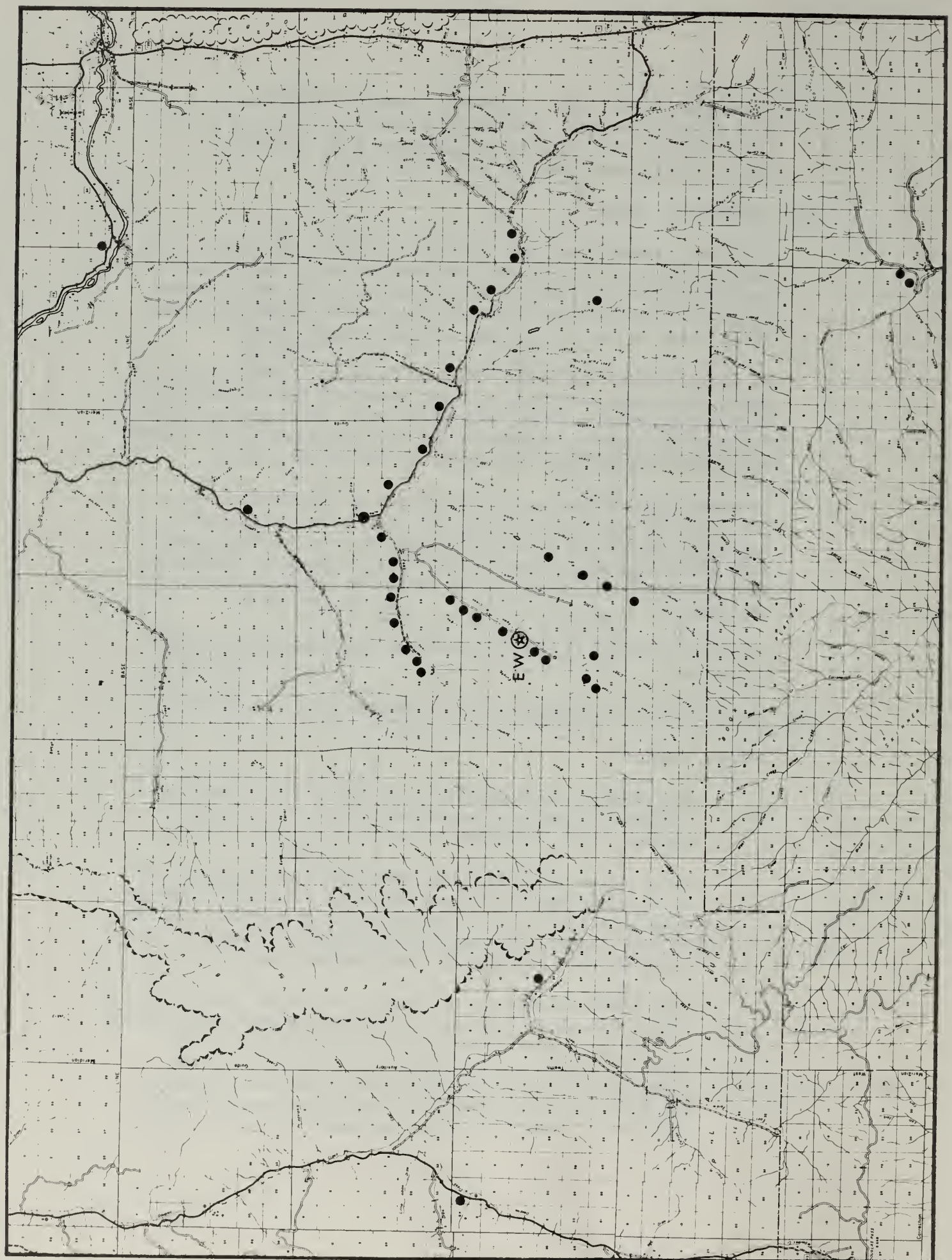


FIGURE IV-9 ROCKFALL LOCATIONS (●), PROJECT RIO BLANCO

Distances between monuments and changes in alignment were measured. These surveys were conducted on three separate occasions, twice predetonation and once postdetonation (except for one location, which was surveyed once predetonation and once postdetonation).

The maximum observed apparent change in elevation between the first and second predetonation surveys was 9 mm. The maximum apparent change between the second predetonation survey and the postdetonation survey was 8 mm, excluding two monuments which were apparently hit by falling rocks dislodged by the seismic wave. (They were covered with rock fragments at the time of the postdetonation survey.) The direction of the elevation differences observed, both predetonation and postdetonation, corresponded, in some cases, with the direction of displacement of the fault blocks and, in other cases, was the opposite. It is concluded that the observed changes are surficial in nature and do not indicate any gross movement along fault planes.

Two components of ground acceleration were obtained from the peak recording accelerometer located at the surface fault trace nearest to the EW (5.5 km). These were:

Longitudinal	1.26g
Transverse	0.94g

The vertical component was not obtained due to a malfunction of the gauge.

Records from the aftershock monitoring stations indicate the maximum distance from the EW at which aftershocks occurred was approximately 880 meters--a considerable distance from the nearest surface fault trace.

Based upon all the data acquired and analyzed to date, it is concluded that the faults investigated were indeed stable and that no movement of the adjoining blocks occurred as a result of the Rio Blanco detonation.

4-5-2 Surface Crack Observations

Pre- and postdetonation photographs of the Fawn Creek Road surface and well pads were taken in an effort to estimate the lateral extent of spall caused by the Rio Blanco detonation.

Road surface documentation stations were selected at approximately 800-meter intervals along Fawn Creek Road both north and south of the EW out to approximately 4.8 km. Before and after photographs of the well pads of the EW, RB-S-04, Fawn Creek Government Number 1, and Boise Number 1 were also made from fixed stations.

Cracks which existed prior to the detonation were noted during station selection and predetonation photographing.

All detonation-related zones of surface cracks observed along the road and on the well pads were documented.

No detonation-related cracks are visible in the photographs made at the fixed stations.

The maximum distances from the EW at which cracks were observed were 4.32 km to the NNE and 2.40 km to the SSW. The nature of the road surface (less hardpacked) at distances greater than 2.4 km to the SSW was not as conducive to crack formation and preservation as that within 2.4 km and to the NNE.

Except for a single 2-cm-wide crack near the EW pad, the maximum observed crack width ranged from less than 0.1 cm up to 0.5 cm, with a median value of 0.2 cm. Lengths ranged to a maximum of 24 m, with a median of 3.5 m.

Essentially, all the cracks observed followed preexisting desiccation cracks. No cracks were observed to continue from the road surface or well pads into adjoining rock outcrops or alluvial fill.

4-6 EFFECTS ON REGIONAL MINERAL PRODUCTION

4-6-1 Mines and Quarries

Minor rockfalls were reported from the walls in the Colony Oil Shale Mine. None of the other inspected mines or quarries, out to 53 miles from the EW, suffered any damage as a result of the detonation.

The evacuation procedures instituted for the eight active mine operations in the area resulted in production delays in only five of the mines; the NuGap Coal Mine near Silt, and the three gilsonite companies in Bonanza, Utah, stopped work for 2-4 hours, while the Redwing Coal Mine, near Axial, was closed for one 8-hour shift. The combined effect was a delay in mining of about 750 tons of coal and about 100 tons of gilsonite.

4-6-2 Oil and Gas Wells

Forty-two wells within seven miles of the EW were inspected and photographed for comparison with predetonation conditions.

No surface damage to any of the wells or ancillary equipment was evident. Within approximately four miles of the EW, some movement of well casings was noted from soil displacement surrounding the casing.

4-7 HYDROLOGIC EFFECTS

4-7-1 Water Wells and Springs

Postdetonation water sample analyses have not been completed; however, the data available indicates no significant difference between the chemical compositions of the water samples taken before and after the detonation. No increase in the turbidity was noticed. Preliminary information from the Colorado Health Department appears to confirm that no significant change in the quality of the use water in the area occurred.

An increase in the yield of springs, as far as 10 miles from the EW, has been observed after the detonation. Although some of this may be attributable to the late melting of the heavy snow cover, the major part of the increase is probably due to the detonation-induced shock wave and a resulting increase in pore pressure. The largest increases in spring yield are noted on Black Sulphur Creek and Fawn Creek where up to about five times normal predetonation readings were made. The degree of the yield increases tapers off toward Ryan Gulch (2-2.5 times predetonation) and East Stuart Creek (1.4 times predetonation).

As of D+30 days, these yields have not decreased.

In the Fawn and Hunter Creek Valleys, new springs have been noted and old spring locations, dry for decades, appear to have been revived by the shock wave.

4-7-2 Aquifer Effects

4-7-2-1 Variation in Transmissivity

Initial tests indicate no significant change in the "B" Zone transmissivity (RB-D-01 Well), and an increase in transmissivity in the "A" Zone (RB-D-02 Well). The "A" Zone results are complicated by equipment problems, so they

must be considered very tentative at this time. If the increase is real, it probably is the result of spalling at the top of the zone. CER is attempting to carefully evaluate the transmissivity changes, and will attempt to pinpoint the intervals of increased transmissivity.

4-7-2-2 Development of Transmissivity Across the Mahogany Zone

There is no indication to date of interference across the Mahogany Zone. One test has been made between RB-D-01 and RB-S-03, and another between RB-D-02 and RB-D-03.

4-7-2-3 Bore Hole Water Level Measurements

Since the detonation of Project Rio Blanco, a continuous log of water levels has been recorded in eight bore holes ranging from 4.8 to 18.0 miles from the emplacement well. Table IV-6 is a short resume of the change in water levels in these bore holes for the period May 17, 1973, to June 28, 1973:

TABLE IV-6

Water Level Measurements in Bore Holes
Project Rio Blanco

Site	Total Depth (Feet)	Cased Depth (Feet)	Distance From EW (Miles)	Change in Water Level As Per Preshot Data (Feet)
Colorado Core Hole 1	3,133	1,050	18	+ 1.8
Colorado Core Hole 3	3,797	2,270	17.6	+ 4.6
Shell 23X-2	2,700	330	7.7	+ 2.0
ARCO 36-1	450	70	6.6	+ 4.0 (until 5/21) - 5.0 (as of 6/28)
Equity Boise CH 1	2,000	305	4.8	+17.4
Mobil Hunter Creek 5	1,745	699	5.6	+ 5.5
TOSCO 71-4	2,050	143	9.0	+ 0.6 (until 5/23) - 0.3 (as of 6/28)
TOSCO 71-2	1,158	130	10.5	-28

4-8 PROMPT BIOENVIRONMENTAL EFFECTS

4-8-1 Surveys

The prompt bioenvironmental effects survey was designed to document bioenvironmental conditions immediately pre- and postdetonation. The survey was performed by consultants from Colorado State University; representatives from the Colorado State Division of Wildlife also participated in making observations.

Extensive documentation and evaluation was concentrated within a radius of approximately 1.5 miles of the EW, although some observations were also made outside this area. The scope of the survey did not include comparison of the effects described below with those effects from natural causes, for example flash floods.

Observers were organized into three teams. Team 1 was concerned with the aquatic and riparian environs of Fawn Creek near the EW. Team 2 focused attention on the terrestrial environs in the immediate vicinity of the EW. Team 3, using a helicopter, reconnoitered a 10-mile radius area from the EW to document nesting raptors and livestock and big game concentrations and responses. All observers were alerted to look for wildlife and livestock that might be injured or killed by ground motion effects.

4-8-2 Effects

No evidence of direct effects of ground motion upon animal life along Fawn Creek was found. However, secondary effects upon animals occurred such as losses of food, cover (habitat), and nests or burrows.

Efforts were made both pre- and postdetonation to document existing animal life and carcasses along Fawn Creek. No freshly dead or injured animals (other than birds) or fish were found postdetonation. Cattle within 400 yards of the EW at detonation time showed no effects. On postdetonation surveys, deer were seen in nearly the same locations and in relatively the same numbers as before the detonation. Twenty-nine cattle, eight horses, and four domestic goats were under observation about six miles from the EW at detonation time. Some of the animals became alert and moved about for a short time, but none demonstrated undue alarm.

Prior to the detonation, 27 burrows of bank swallows and small mammals along the surveyed banks of Fawn Creek were documented. Following the detonation, six of the burrows were intact, while 21 had been obliterated by bank sloughage.

Six beaver dams on Fawn Creek approximately six miles from the EW were not noticeably altered by the ground motion.

Dens of marmots, golden-mantled squirrels, and chipmunks that were marked on predetonation surveys could not be relocated after the test because of burial by rockslides and debris, especially within a 1.5-mile radius of the EW. No injured or dead small mammals were documented within the 2-mile radius of the EW. However, it is reasonable to assume that many burrows were occupied at the time of the detonation and that many small mammals, birds, and reptiles were crushed or suffocated.

Birds in the immediate vicinity of the EW were affected by rockfalls. At least 35 cliff swallow nests were destroyed. Many of these nests were abandoned prior to the surveys. One cliff swallow colony 1.5 miles up valley from the EW was completely destroyed by rockfalls and two crushed swallows were found.

In predetonation surveys, three active golden eagle nests, eleven active red-tailed hawk nests, and five inactive nests were documented. On postdetonation surveys, four hawk nests with five eggs were found destroyed or abandoned. The golden eagle nests appeared to be unaffected.

Directly observable impacts to vegetation in the terrestrial study areas were the losses of trees, shrubs, grasses, and forbs that were displaced from cliffs, as well as the vegetation buried or broken by the falling debris.

A major impact on the majority of animal species was the loss and alteration of habitat. Population adjustments will occur to adapt to the changed conditions.

Within a 1.5-mile radius of the EW, damage to aquatic and riparian habitat along Fawn Creek was severe and common. Severe to moderate effects upon habitat from slides and rockfalls were also common on the steeper, south-facing hillside slopes within this radius. Moderate damage to aquatic and terrestrial habitats in very specific, localized areas was documented in a zone 1.5 to 10 miles in radius from the EW.

As expected, pressure waves from the explosion compressed the groundwater and caused prompt increases in stream and spring flow. The flow of Fawn Creek was measured 1.3 miles below the EW pre- and postdetonation. At 1655 hours on May 16, the flow was 3.17 cubic feet per second and at 1655 hours on May 17, the flow was 9.21 cubic feet per second. A spring located 1.5 miles above the EW increased in flow by at least twofold. A spring 0.8 miles above EW developed a second opening and the total flow increased by approximately threefold.

The detonation resulted in a substantial prompt increase in the silt load of Fawn Creek and a minor increase in dissolved solids. The spring 1.5 miles above the EW showed an approximate threefold increase in suspended solids, but no increase in dissolved solids. The cause of the increased silt load was undoubtedly a combination of sloughage material and increased stream flow and turbulence. The total silt load at 1.5 miles below the EW increased from 12 cubic yards per day the afternoon before detonation to 354 cubic yards per day on the afternoon of D-day. By the following morning, the concentration of suspended solids had decreased by 58 percent of the amount measured on the afternoon of D-day.

It should be noted that snow melt had been accelerated by the arrival of warm weather a few days before D-day. As a result, Fawn Creek had swollen and was carrying an appreciable sediment load even before the detonation. These conditions prevented meaningful assessment of effects on the aquatic fauna.

The steeper, nonvegetated banks of the Fawn Creek near the EW underwent significant additional sloughage as a result of ground motion. (In many places, bank sloughage has been occurring spontaneously from undercutting by the stream.) It was visually estimated that within the stream section from 1.0 mile below to 1.2 miles above the EW, approximately 50 percent of the lineal footage of both banks underwent sloughage of about one cubic foot to two cubic yards per lineal foot of bank. This translates into an estimated total of about 14,000 cubic yards of soil sloughed from the banks along this section of the creek.

The principal ecological effects of bank sloughage include: (1) increased siltation of Fawn Creek, (2) temporary damming of Fawn Creek, (3) burial of herbaceous vegetation growing on the flood plain by silt deposition, (4) burial of riparian vegetation by rubble or silt,

(5) loss of shrubs along the bank edges, and (6) loss of bird and small mammal burrows and habitat along and at the base of the steep banks.

Between 1.0 mile below and 1.2 miles above the EW, it is estimated that stream bank sloughage and burial by silt on the flood plain resulted in loss of approximately 11,000 shrubs (or less than 1 percent of the shrubs present in this segment of Fawn Creek Valley) and 1,100 pounds (dry weight) of herbaceous vegetation.

4-9 SUMMARY OF PREDICTED VS OBSERVED EFFECTS

4-9-1 General

The probable impact on the environment resulting from Project Rio Blanco has been discussed extensively in numerous reports, including the Environmental Statement (WASH-1519) and Addendum, and public meetings held prior to the execution of the project. Although much of the data presented in this report must be considered as preliminary and only limited analyses have been performed, a correlation of predicted vs observed effects is presented for those programs where sufficient data are available in Table IV-7.

4-9-2 Ground Motion

The ground motion predictions made by CER used prediction techniques based on the results of the Rulison detonation. Regression analyses of observed velocity data for hard rock stations were less than predetonation predictions.

4-9-3 Ground Motion Effects

A comparison of ground motion effects predictions and actual effects is given in Table IV-7.

4-9-4 Aftershocks

On the basis of previous detonation experience, it was expected that no more than a few dozen aftershocks would occur, none having an equivalent Richter magnitude greater than 3 (compared with equivalent Richter magnitude 5.5--body wave--for the explosion itself). Aftershocks were predicted to cease within a few hours.

The aftershocks generated by Project Rio Blanco were located within a few thousand feet of the explosion cavity. There were relatively few aftershocks. Most occurred within hours and all within eight days. All aftershocks detected had magnitudes less than 2.5.

Table IV-7

Comparison of Effects Predictions and Actual Effects

CATEGORY	PREDICTED EFFECTS	ACTUAL EFFECTS
Residential structures	Minor architectural damage ($50,000 maximum)	Minor architectural damage (less than $14,000 thus far)
Industrial facilities	No damage (except possibly the Equity Plant)	Minor damage at Equity Camp
Bridges	No damage	No damage
Tunnels	No damage	No damage
Power and telephone lines	No damage	No damage
Communication facilities	No damage	No damage
Gas & oil wells	No damage	No surface damage
Mines	No damage	Minor rockfalls from walls of Colony Mine
Hydraulic features	No damage, except minor damage to small irrigation ditches (sloughing of banks)	Minor damage to small irrigation ditches (sloughing of banks)
Airports	No damage	No damage
Railroads	No damage	No damage
Roads	No damage (possible temporary blockage due to rockfalls)	Temporary blockage due to rockfalls
Water wells and springs	Slight temporary increase in flow and turbidity	Larger increases in flow rates than anticipated and to a greater areal extent. In many instances, flow rates have not returned to predetonation levels. Appreciable but temporary increases in sediment levels to Fawn Creek.

Table IV-7 (Cont.)

CATEGORY	PREDICTED EFFECTS	ACTUAL EFFECTS
Rockfalls and Landslides	Minor rockfalls and landslides predicted in areas controlled by evacuation and roadblocks. Snow avalanches not predicted due to May detonation.	Significant number of rockfalls within area controlled by evacuation and roadblocks. No avalanches.
Ecological effects		
1) Vegetation	1) Localized damage near the EW to vegetation from slides and rockfalls, sloughing of gully banks, and motion-induced damage to shallow-rooted species.	1) Localized damage to vegetation from slides and rockfalls, sloughing of gully banks.
2) Animals	2) Localized damage near the EW to animals from slides and rockfalls.	2) No injuries to deer, cattle, or horses were detected. Localized damage to small animals and birds, their food supplies, habitat, burrows, and nests from rockfalls and landslides.

V. ADD-ON PROGRAMS Compiled by B. G. DiBona, AEC/NV

5-1 SANDIA LABORATORIES PORE PRESSURE AND GROUND MOTION MEASUREMENTS

Sandia Laboratories, operating with funds obtained from the National Science Foundation, measured changes of water pore pressure in saturated soils of the Fawn Creek Valley. Changes in water pore pressure are a good index of the small amount of consolidation which precedes soil liquefaction. The ground motion waves developed on Rio Blanco impose a seismic input similar to an earthquake, so Rio Blanco provided an opportunity to study pore pressure changes in indisturbed soils.

The pore pressure measurement stations were located at 2.1, 4, 7, and 10 km from the EW in the northeasterly direction along Fawn Creek. Ground motion acceleration histories of the three orthogonal components (vertical, radial, and tangential) were obtained at all stations for correlation with pore pressure records. The instruments and recording system operated satisfactorily and all data were obtained.

In the interval between the drilling holes and installation of pressure transducers, several holes dried up. It was necessary to irrigate these to restore saturated media about the measurement points. Inspection of the records suggests that this corrective measure was successful except possibly for the station at 4 km. The medium at this station was so impermeable that very little water could be forced into the formation and the small observed effect may, in part, represent the response of the sand about the transducer rather than that of the medium.

Sustained increases in soil water pore pressures were observed at all stations but no pressure levels rose so high that liquefaction would be expected. Table V-1 lists the peak and +10 second values of the pore pressure increase. Playbacks with slower sampling rates will be necessary to fully establish the character of the subsidence of these pore pressure enhancements.

Three effects worthy of note were observed. The first was that significant pressure increases were observed before spall closure at the two closer stations. The second and more expected trend was that measurements in less permeable material showed smaller pressure oscillation than those in more permeable media even though the sustained pressure increases were about the same. Finally, inspection

of the records reveals there is the expected close correlation between the transient values of pore pressure and vertical acceleration. It is also apparent that radial accelerations are affecting pore pressures in the later portion of the traces.

TABLE V-1

Preliminary Summary of Pore Pressure Increases

Station Distance (km)	Approximate Measurement Depth (ft)	Peak Pressure Increase (psi)	Sustained Pressure at 10 Sec. (psi)
2.1	13	4.4	1.3
	21	1.7	1.7
4	21	0.7	0.10
7	18	1.2	0.4
10	9	0.33	0.29
	21	1.2	0.10

The ground acceleration time histories show some interesting trends. Two spall closures were observed at the stations at 2.1 and 4 km. The peak values of the initial accelerations were about those predicted at these two stations. Peak values of spall closure acceleration are not predictable but a maximum value of 30 g's was assumed in assigning set ranges. Peak radial acceleration at the 7 km station exceeded the predicted value while the ground motion at the 10 km station was somewhat weaker than expected. Peak values and arrival times are listed in Table V-2.

TABLE V-2

Preliminary of Summary of Peak Accelerations

Station Distance (km)	Arrival Time (sec)	Situation	Vertical (g)	Radial (g)	Tangential (g)
2.1	0.95	First signal	-	-	-
	0.99	Initial peak	3.9	0.24	0.14
	1.22	Spall closure	18	-3.0	0.64
	1.39	Spall closure	1.6	0.63	1.82
4	1.35	First signal	-	-	-
	1.39	Initial peak	3.3	0.16	0.06
	1.58	Spall closure	7.5	1.9	2.1
	1.72	Spall closure	2.3	1.6	1.7
7	1.97	First signal	-	-	-
	Component peaks come at different times		0.82	1.6	0.16
10	2.62	First signal	-	-	-
	Component peaks come at different times		0.20	0.30	0.16

5-2 U.S. GEOLOGICAL SURVEY/NATIONAL CENTER FOR EARTHQUAKE RESEARCH (USGS/NCER) CAVITY COLLAPSE AND AFTERSHOCKS

NCER emplaced 33 seismometers within 5.8 km of the EW to measure time history and physical characteristics of cavity collapse and close-in triggered aftershock activity.

Twenty-five stations were completely successful. Four stations which had lines cut by rockfalls at detonation time were back in operation at H+5 hours. All systems were turned off at approximately H+20 hours. Data from these stations have not been received.

5-3 EL PASO NATURAL GAS COMPANY

5.3.1 Program Objectives

The primary objective of this work is to further improve the accuracy of effects predictions of underground-nuclear-explosion induced ground motions upon man-made and natural structures and the bioenvironment near the detonation point. A number of structures

exist near the Rio Blanco EW which are similar to structures near the proposed Wagon Wheel Project. Project Rio Blanco provides an opportunity to improve capabilities for evaluations relative to Project Wagon Wheel.

The following specific objectives will be supportive of this primary objective:

a. Determine the increase and decay of pore-water pressure in saturated, loosely consolidated sands over several hours duration to determine the potential of these sands for liquefaction due to high amplitude, short duration pulses of a limited number of cycles characteristic of nuclear detonations.

b. Determine the potential for the occurrence of permanent and transient deformations with regard to small, single-span bridges typical of those associated with ranching operations and rural transportation.

c. Determine the potential for rock falls and minor sloughage from slopes of comparable material and geometry as those found near Project Wagon Wheel.

d. Determine if wave lengths in ground motion exist such that large strains can be induced in structures of a few hundred feet in length by the ground motion from the detonation.

e. Investigate the effects upon mechanical structures characteristic of conventional gas field operations.

f. Investigate the effects upon vegetation.

5-3-2 Pore-Water Pressure Measurements

Measurements of pore-water pressure changes were made using electric piezometers in two holes at 9.98 km and a third hole at 22.85 km from the EW. Depths of transducers ranged from about 17 feet to over 30 feet with ambient pore-water pressures ranging from about 0.5 psi to 7.0 psi. Table V-3 shows a summary of preliminary results obtained from the piezometers. Figure V-1 shows a typical piezometer signal.

Table V-3

Preliminary Results of Piezometer Data

Unit	Site	Depth (ft)	Soil Type	Hydro-static Pressure (psi)	Litho-static Pressure (psi)	Transient Peak Pore-Water Pressure (psi)	Average Pressure Buildup During Motion (psi)	Last Time Pressure Exceeded 10% of Peak (sec)
PE-1	EP-17-3	27.5	SW, sand	5.0	14.8	2.83	0.74	12
PE-2	EP-17-3	21.7	SW, sand	2.4	13.0	1.98	<0.1	6
PE-3	EP-17-1	17.2	ML, silt	0.5	12.2	0.56	0.34	20
PE-4	EP-17-1	30.4	ML, silt	6.2	16.3	3.75	0.65	7
PE-5	EP-17-1	26.7	SM, silty sand	4.6	15.1	1.82	<0.1	6
PE-6	EP-17-1	21.7	SP, sand-poorly graded	2.4	13.6	2.16*	<0.1*	<6
PE-7	EP-6-2	28.3	SP, sand-poorly graded	7.0	13.9	1.77	0.91	53
PE-8	EP-6-2	19.7	SM, silty sand	3.7	11.2	0.83	0.13	30

*Instrument base line shift makes analyses uncertain.

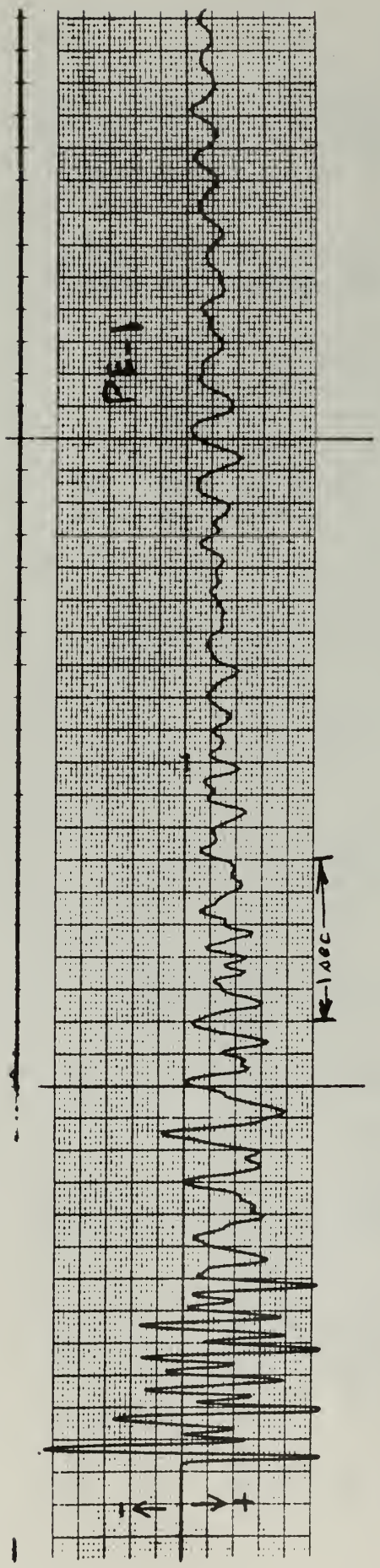


FIGURE V-1 A TYPICAL PIEZOMETER SIGNAL (PE-1) SHOWING BOTH A TRANSIENT INSTANTANEOUS RESPONSE TO GROUND MOTION AND A LONGER TERM AVERAGE PORE PRESSURE INCREASE WHICH DIES AWAY IN ABOUT 8 TO 10 SECONDS.

All eight transducers functioned properly. Transient pressure changes correlated well with signals obtained from nearby accelerographs. All first pulses indicated an increase in pore-water pressure corresponding to a compression force in the initial seismic signal. Several longer-term changes were noted in average pore-water pressures. All but one of these changes in average pressure were positive and decayed away in times of tens of seconds. One transducer (PE-6) indicated a small negative change in average pressure which persisted indefinitely. At first this was reported to be a real change, but more careful analysis of the record plus the long persistence indicates a base line shift inherent in the instrument's mechanical peculiarities.

5-3-3 Earth Strain Cables

Earth strains at the surface at 10.0 km were measured by means of stretched cables between anchored piers. Ten individual sections of cable ranged from 25 to 200 feet in length and the composite length was 600 feet. Orientation was approximately radial to the emplacement well. Good signals were obtained on all channels. Results indicated that six of the cables and transducers responded freely to the ground displacements resulting in good data. The end of the cable sequence, including the longest lengths, was laid on undulating terrain. This resulted in frictional forces impeding their response. As a result, the relative displacement wave forms and amplitudes were sufficiently distorted so as to render any analysis meaningless.

Table V-4 shows the summary of preliminary results obtained from the strain measurements. Figure V-2 shows a typical strain recording.

The analysis on the six good transducers indicates that predominant frequencies were of about 4 and 6 Hz. By utilizing preliminary measured accelerations and calculated velocities obtained at this location, together with the ratios of acceleration, velocity, and displacement from preshot predictions, it is calculated that peak displacements in the horizontal plane were about 0.5 cm. Peak relative displacements were only 0.12 cm or about 25 percent of peak displacement. By assuming that the seismic signals are nearly sinusoidal, it follows that the peak relative displacement occurs between two points

TABLE V-4

Preliminary Results of Earth Strain Data

Unit	Length (ft)	Peak Relative Displacement (cm)	Preliminary Results Time of Peak Amplitude (sec)	Frequency of Peak Motion (Hz)	Calculated Wave Length (ft)	Calculated Wave Velocity (ft/sec)
1	25	0.065	0.9	4.2	1,200	5,040
2	25	0.068	0.9	4.0	1,155	4,620
3	50	0.076	0.75 and 1.0	4.0 and 6.2	2,070	8,275 and 12,830
4	50	0.118	0.75	6.2	1,350	8,370
5	50	0.121	0.85	6.2	1,300	8,060
6	50	0.070	0.75	6.0	2,250	13,500
7	100	-	-	-	-	-
8	50	-	-	-	-	-
9	100	-	-	-	-	-
10	200		-	-	-	-

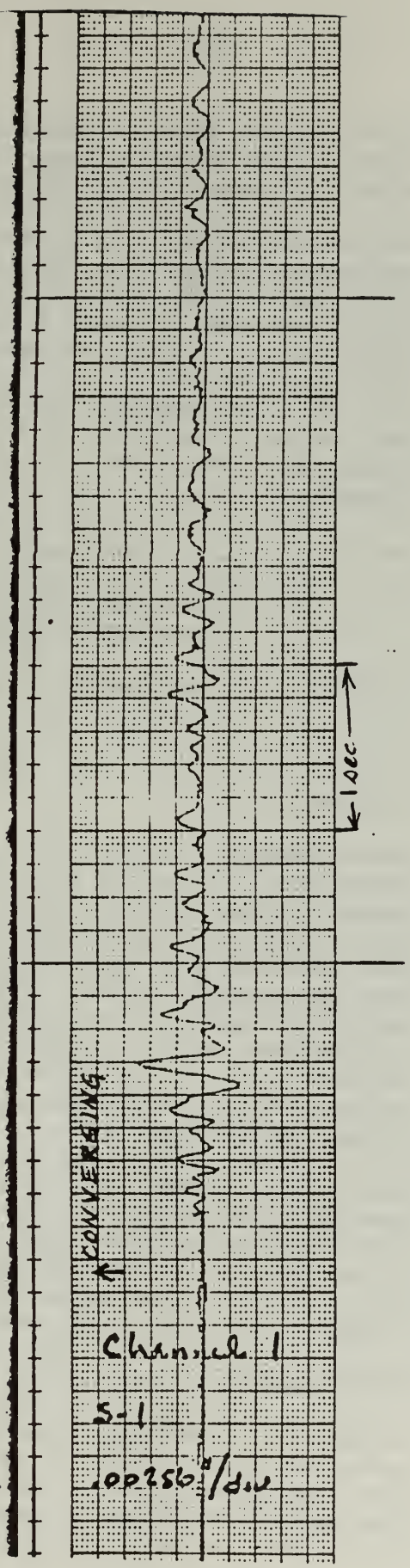


FIGURE V-2 A TYPICAL RECORD OF A STRAIN MEASUREMENT (50 FEET LENGTH)

when the point midway between the measuring points is passing through its rest position, i.e., when the slope of the displacement signal is at its maximum.

The analysis indicates the presence of at least two distinct arrivals in the high amplitude, early part of the record. The earlier arrival appears to exhibit frequencies of about 6 Hz, velocities of about 8,200 feet per second, and wave lengths of about 1,325 feet. The later arrivals show frequencies of about 4 Hz with corresponding velocities of about 4,830 feet per second and wave lengths of about 1,175 feet. Wave lengths were calculated by the following relationship:

$$\lambda = \frac{360}{\arcsin \frac{\text{Peak relative displacement A}\rightarrow\text{B}}{2 \times \text{peak displacement}}} \times \text{length A}\rightarrow\text{B}$$

Velocities are calculated by the familiar relationship:

$$v = \lambda f.$$

5-3-4 Bridges

Three bridges at 10.94, 11.1, and 12.55 km were instrumented with scratch and deflection gauges to monitor relative motion between bridge components. Preliminary analysis of these records indicates some discrepancy between values measured by scratch gauges and photographically recorded dynamic dial gauges. More complete analysis is being done to resolve these differences. Hairline cracks were observed in the abutment fills on the bridge showing the greatest deflections on the scratch gauges. No damage to any bridge could be detected.

Engineering surveys of all bridge dimensions and positions were obtained preshot and postshot. Preliminary results indicate no permanent deformations in excess of the survey accuracy of 0.01 feet occurred to any bridge components with the exception of minor cracks in the abutment fill of one bridge.

5-3-5 EPNG Compressor Station 24

Accelerations and velocities were successfully measured at several points in and on equipment at EPNG's gas compression plant at about 18.8 km. Engineering surveys were made of dimensions and positions throughout the facility. No deformations in excess

of the survey accuracy of 0.01 feet were found in the postshot surveys inasmuch as good closure was obtained in all internal survey points. Only one item was found to have moved at Station 24. The surveyors used the standard technique of establishing a bench mark by driving a nail in a nearby telephone pole. Postshot surveys indicate that this pole moved upward during the ground motion and stayed up approximately 0.5 inches above preshot elevation.

5-3-6 Bluffs and Slopes

Several bluffs and slopes, including steep ditch banks, were selected for pre- and postshot engineering surveys and photographs. No massive slides or slope movements occurred on any of the bluffs and slopes selected for the EPNG study. Most falls consisted of individual rocks or groups of rocks. Photo documentation was made of rockfalls along Piceance Creek, Black Sulphur Creek, and Stuart Gulch. The summary of findings is shown in Table V-5. Piceance Creek was examined for several miles on either side of the Rock School for bank failures. The only failures detected appeared to be at least a year old, since grass had taken good root on all scarps and exposed surfaces.

5-3-7 Plant and Vegetation Study

Six 20-square-foot vegetation areas were established and quantitatively and photographically documented preshot. Four of these locations were within 1,000 feet of the EW, with the other two locations being adjacent to EPNG study bluffs and slopes at 8.0 and 11.26 km from the EW.

Documentation was then made within 24 hours postshot and again one week later. These plots will be observed this fall to complete a study intended to document the effects directly related to the shot. A report will be forthcoming at that time. From early observations, the only significant effect of ground motion was that relating to minimal sloughage of steep banks and loss of plants existing very near those banks. On the close-in plots and adjacent relatively level surfaces, some soil disturbance was observable, but was not reflected by plant wilting or cessation of growth.

TABLE V-5

Rockfalls and Slides

Area	Location (miles from junction)	Approximate Volume of Fall or Slide (cu yds)
Black Sulphur Creek from ECC to Rock School	1.1	1
	1.0	7 (off road)
Black Sulphur Creek from ECC to Equity Plant	0.25	3
	1.3 - 1.85	<1 (several small falls)
	1.9	1.5
	2.2	1.5
	2.5	6 (several small falls over .3 miles)
	4.0	4 (soil slump)
	4.0 - 4.7	<1 (several small falls)
	4.75	5
	4.8 - 8.1	<1 (several small falls)
Piceance Creek from Rock School to White River City	0.6	<1
	5.3	1
	5.5	<1.5
	5.6	1
Piceance Creek from Rock School to Rio Blanco	3.0	10 - 15
	6.6	3
	11.2 - 11.7	40 (one very large boulder plus several smaller ones)
	13.3	2 - 3
East Fork of Stuart Gulch from Piceance Creek Road	3.25	10
	3.7	3

5-4 U.S. BUREAU OF MINES SEISMIC EFFECTS ON OIL SHALE

5-4-1 Colony Oil Shale Mine

One hundred and forty-eight paper gauges were installed over joints and faults in the mine pillars and roof. Any resulting displacements along these joints from the Rio Blanco Event were not sufficient to fracture the paper gauges.

Twenty Carlson strain and stress meters were installed in the mine, nine of which were connected to continuous recorders. These gauges were installed across visible cracks in the roof, floor, and pillars. Results indicate that displacements caused by the wave passage from the detonation of Rio Blanco are within the accuracy limits of the instruments. Opening and/or closure of the cracks if any was less than ±100 microinches.

Thirty-eight sagmeters and forty-two convergence stations were monitored before and after the Rio Blanco event. These data are being studied, but preliminary analysis indicates that no significant effects resulted from the Rio Blanco detonation.

Two TDC-1 systems using L-1513 geophones were installed by ARCO. To date, these records have not been received.

Five SMA-1, three-component Strong Motion Accelerographs were installed by Kinemetrics. Data from these stations has not been received.

Four geophones were installed by Dames and Moore to monitor rock noise before and after the detonation of Rio Blanco. These data have not been received.

An L-7 system was installed just inside the mine portal, on the floor, by the USGS/SEB. Data from the station indicates a peak particle velocity of 1.259 cm/sec at a frequency of 5.9 Hz. See Table IV-1.

The USBM, Denver Mining Research Center, instrumented and monitored six stations in the mine. The six stations were instrumented with seven HS10-2 vertical velocity gauges and one accelerometer. The single accelerometer was mounted on the roof near an HS10 installation. This was done to get a direct comparison between acceleration and particle velocity. An HS10 was also installed on the floor near the mine portal, within a few feet of the L-7 system.

A total of eight data channels were recorded, seven particle velocity and one acceleration. Data quality was excellent, all gauges were recorded with no data loss. Preliminary examination of the data indicates the following:

Peak acceleration	0.034 g
Average peak particle velocity	0.896 cm/sec
Maximum peak particle velocity	1.318 cm/sec
Minimum peak particle velocity	0.703 cm/sec

Nominal frequency for peak amplitudes is 4.9 Hz; however, the data analysis is not complete.

The maximum particle velocity was measured at a roof station where the unsupported roof area was large. The minimum was measured at a floor station, on solid material. The comparative acceleration/particle velocity was taken at a narrow roof span area. The particle velocity at this station was: 0.803 cm/sec peak and the floor directly below, .704 cm/sec peak.

The peak particle velocity measured inside the mine portal near the L-7 system was: .935 cm/sec at a nominal frequency of 4.6 Hz. This frequency appears to be somewhat lower than other stations in the mine.

The corrected arrival time of the Rio Blanco detonation at the Colony mine was: 10:00:06.845 hours MDT.

5-4-2 USBM Mine at Anvil Points

Three stations were instrumented and monitored by the USBM, Denver Mining Research Center. Each station was instrumented with an accelerometer and an HS10-2 vertical velocity gauge. These three stations were also instrumented with HS10 gauges for the Rulison detonation.

Data quality was excellent, all gauges were recorded with no data loss. Preliminary evaluation of the data indicates the following:

Average peak acceleration	0.011 g
Average peak particle velocity	0.251 cm/sec

Data analysis is not complete; however, the peak amplitudes appear to be at a nominal frequency of 3.8 Hz. Comparative data from the Rulison detonation are:

Average peak particle velocity	1.08 cm/sec
Frequency	4.3 Hz

The corrected arrival time of the Rio Blanco detonation at the Anvil Points mine was: 1000:09.55 hours MDT.

5-4-3 Carbondale, Colorado

A single station was instrumented with an HS10-2 vertical velocity gauge. Arrival time cannot be determined, since no radio time was available. Magnitude and frequency of the ground motion has not been evaluated; however, the data quality is excellent.

5-5 JOHN A. BLUME & ASSOCIATES GROUND MOTION AND STRUCTURAL RESPONSE

JABAE, with support from the National Science Foundation, is investigating the relationship between ground motion and low-rise building damage. The emphasis here is directed to the evaluation of damage in the range of response accelerations from 0.01g to 0.1g.

Complementing CER instrumentation program, 10 additional 3-component, L-7 ground motion systems were placed in 5 towns (Rangely, Meeker, DeBeque, Grand Valley, and Rifle) surrounding the project area. These instruments were located and installed by the USGS/SEB in cooperation with JABAE and the University of California at Los Angeles. Including CER's instruments, a total of 17 stations recorded usable data in 5 towns. Figure V-3 shows the station locations in each town and the peak motions measured. The motion records are currently being digitized for subsequent computer analysis.

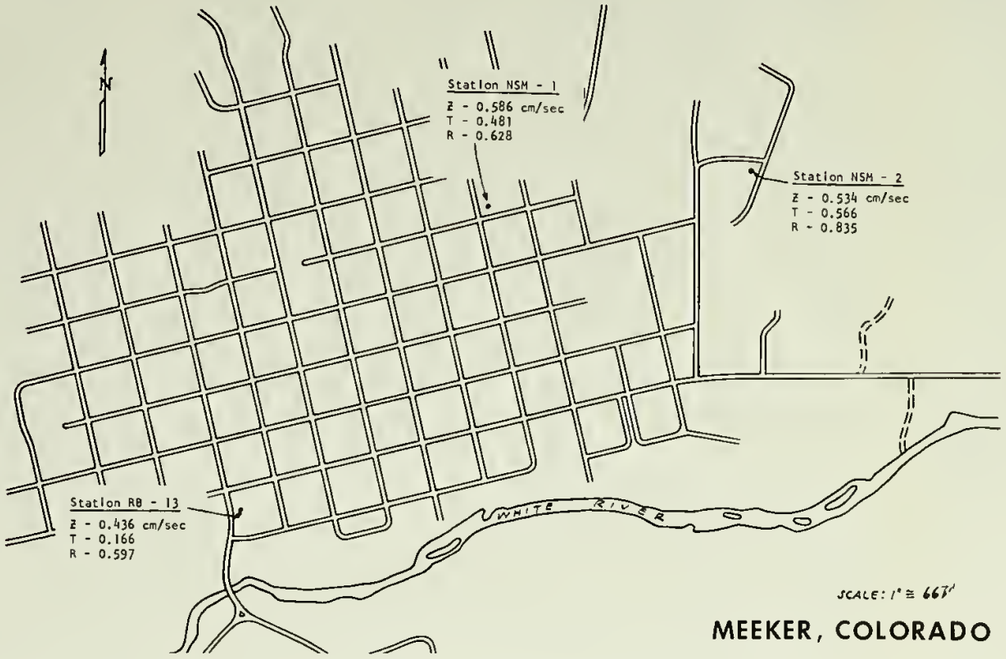
After the low-rise building damage claims for the towns shown in the figures have been settled, the damage statistics will be correlated with the ground motion records.

5-6 SUPERIOR OIL COMPANY SEISMIC EFFECTS ON OIL SHALE

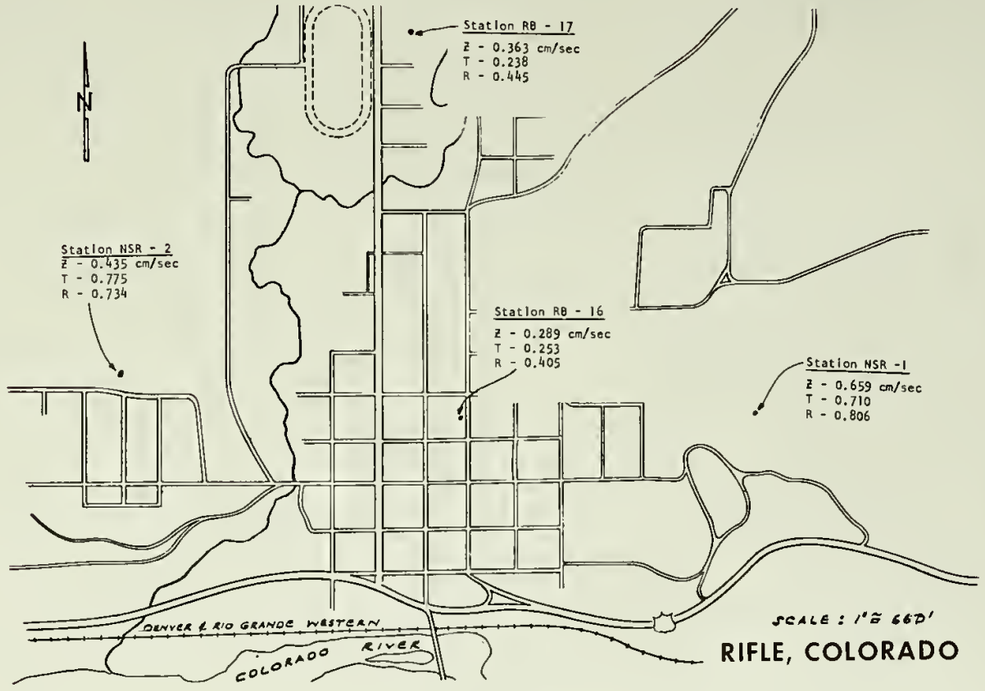
Superior instrumented bore holes on their lease located approximately 24 km from the EW to determine the effect of seismic waves on oil shale. No information is currently available on this program.

5-7 CER GEONUCLEAR STRONG MOTION MEASUREMENTS

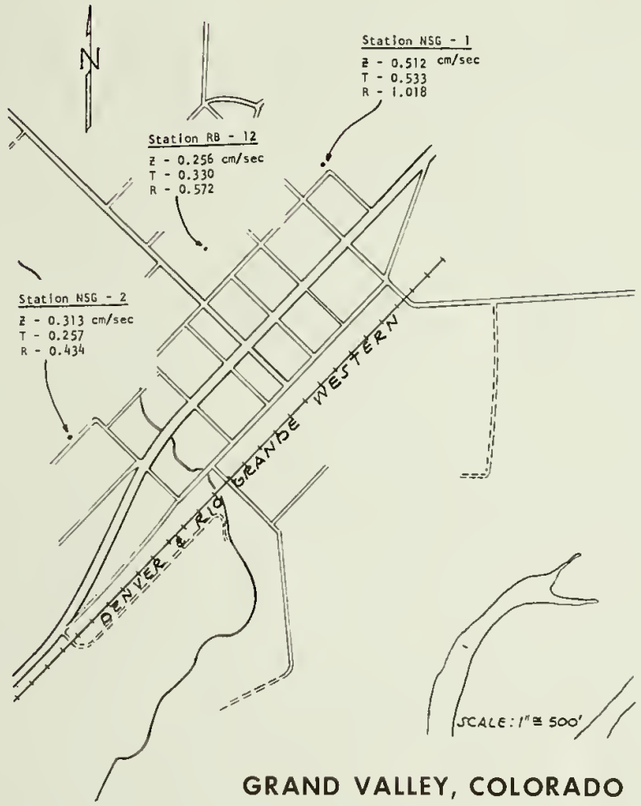
The purpose of this experiment was to deploy two types of strong motion equipment for Project Rio Blanco and to compare the data from them with each other and with the L-7



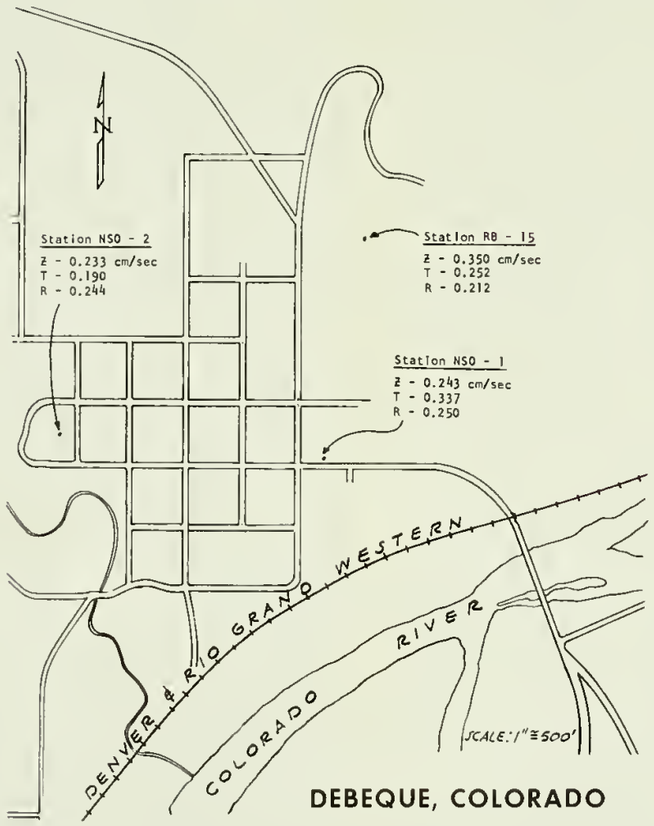
MEEKER, COLORADO



RIFLE, COLORADO



GRAND VALLEY, COLORADO

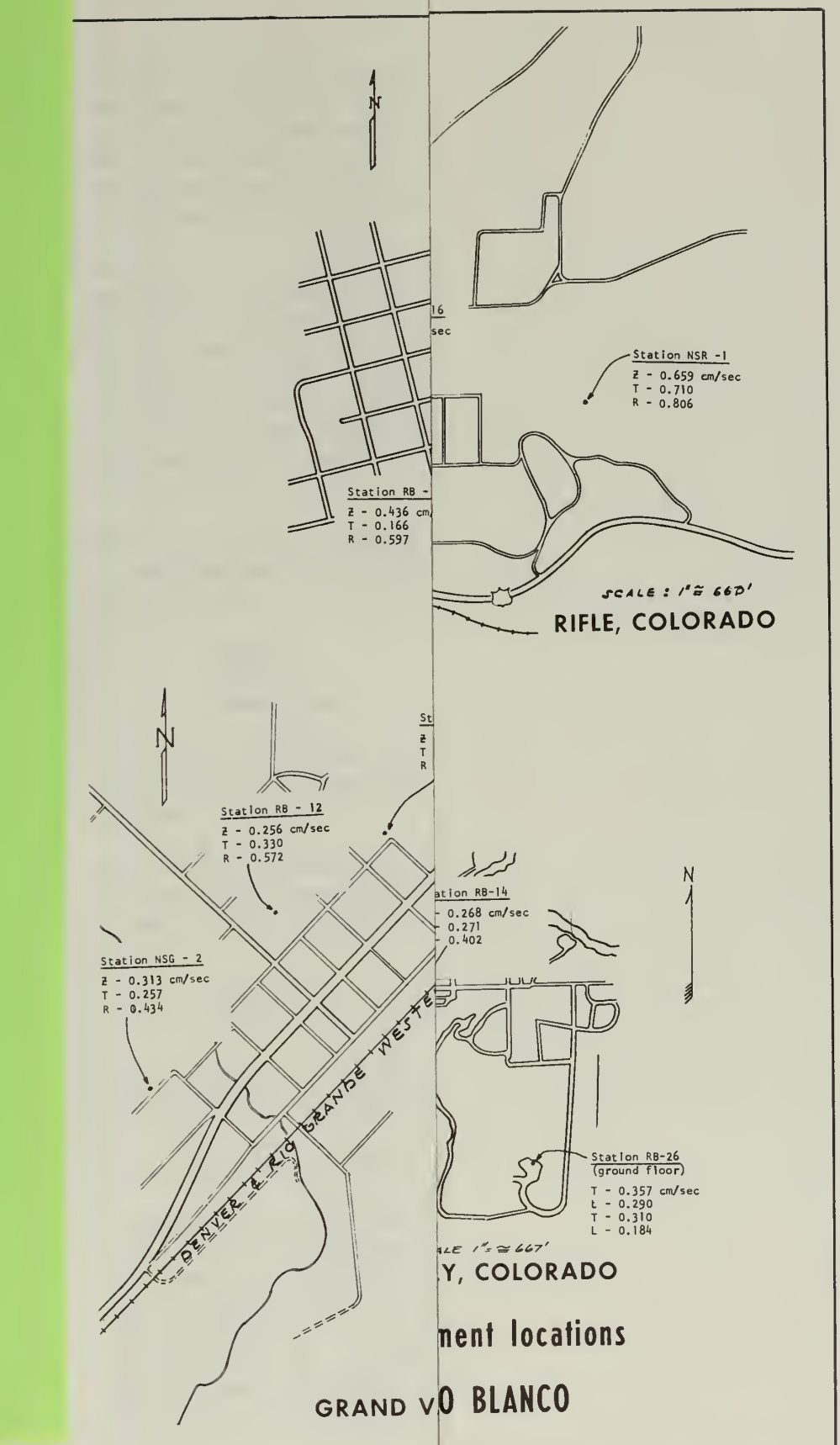


DEBEQUE, COLORADO

RANGELY, COLORADO

FIGURE V-3 **JABARD Instrument locations**

PROJECT RIO BLANCO


N
Station NSR -1
z - 0.659 cm/sec
T - 0.710
R - 0.806
Station RB -
z - 0.436 cm/
T - 0.166
R - 0.597
SCALE : 1"≅ 660'
RIFLE, COLORADO
N
Station RB - 12
z - 0.256 cm/sec
T - 0.330
R - 0.572
Station RB-14
- 0.268 cm/sec
- 0.271
- 0.402
Station NSG - 2
z - 0.313 cm/sec
T - 0.257
R - 0.434
DENVER & RIO GRANDE WESTE
Station RB-26
(ground floor)
T - 0.357 cm/sec
L - 0.290
T - 0.310
L - 0.184
Y, COLORADO
ment locations
GRAND V O BLANCO

systems. The two types of equipment were the Kinemetrics SMA-1 and the Geotech RFT-250. The film magazines were loaded and threaded into the equipment by the manufacturers. The instruments were deployed and operated by CER personnel. The equipment was then returned to the manufacturers, who removed and developed the film and made the analysis.

One SMA-1 and one RFT-250 were deployed beside the L-7 system at the Rock School. The other SMA-1 was deployed at the Cascade Pump Station. The second RFT-250 was deployed at the Shell Plant. Upon the return of the instruments to the manufacturers, it was discovered that neither of the instruments at the Rock School operated properly due to the jamming of the film in the magazine. This instrument failure made it impossible to compare any of the data from the various types of equipment.

The data from the strong motion equipment (Kinemetrics SMA-1) at the Cascade Pump Station have been analyzed visually and given values of acceleration as follows:

Vertical	0.161g
Radial	0.276g
Transverse	0.250g

This record will be processed to obtain values of velocity and PSRV. The surface classification at this station was unknown.

The data from the strong motion equipment (Geotech RFT-250) at the Shell Plant have been analyzed visually and give values of acceleration as follows:

Vertical	.23g
Radial	.20g
Transverse	.15g

This record will be processed to obtain values of velocity and PSRV. This station is known to be on alluvium.

5-8 CER GEONUCLEAR ALLUVIAL TEST WELL PROGRAM

There have been no abnormally "high" salinities encountered in any of the 10 wells being sampled in this program. (The high salinities would indicate a contribution from the "bed" rock, perhaps via fractures or faults opened by the Rio Blanco detonation.) In general, the salinities are decreasing, probably as a result of the high surface water levels and greater than normal runoff, which results in an increase in the freshwater aquifer recharge.

The sampling will continue on a frequency of one per well per week until after the first week in August when the frequency will be reduced to one per well per month (weather permitting). If any anomalous salinities are encountered, the well of interest and nearby wells will be resampled to determine if the anomaly was a sampling or analysis error. If it appears that an anomalous situation has occurred, a revised sampling program will be developed in coordination with the Colorado Water Pollution Control Commission, State Geologists, State Engineer's Office, USGS, AEC, and LLL.

5-9 ATLANTIC-RICHFIELD COMPANY GROUND MOTION STRUCTURAL RESPONSE

ARCO deployed 11 seismic monitoring stations--one each on three oil shale leases held by ARCO and eight seismic stations within the Colony Oil Shale Development Site on Parachute Creek. Data have been received from two of these seismic stations. The locations of these stations and the recorded data are shown in Figure V-4 and Table V-6 respectively.

5-10 ENGDAHL ENTERPRISES PEAK SHOCK SPECTRUM MEASUREMENTS

At the request of Engdahl Enterprises of Costa Mesa, California, CER installed an Engdahl Peak Shock Spectrum Recorder for Project Rio Blanco. This instrument was installed on the heater at the Equity Oil Company plant. The data recorded is shown in Table V-7 and in Figure V-5.

Table V-7

Calibration and Test Data Sheet Peak Shock Recorder™

Reed Number	Frequency (Hertz)	Acceleration Sensitivity (g/inch)	Displacement (inches)	Equivalent Static Acceleration (g)
1	2.02	.360	1.21	.44
2	2.47	.533	1.74	.43
3	3.33	.833	1.29	1.08
4	4.04	1.41	1.69	2.38
5	5.18	2.06	1.12	2.31
6	6.60	3.36	1.03	3.46
7	8.38	5.23	.31	1.6
8	10.5	7.85	.47	3.7
9	13.0	12.9	.26	3.4
10	16.5	20.6	.076	1.56
11	21.8	27.8	.056	1.56
12	25.4	41.6	.041	1.7

Damping: 2 percent viscous damping (Q of 25)
Calibration Date: July 22, 1972

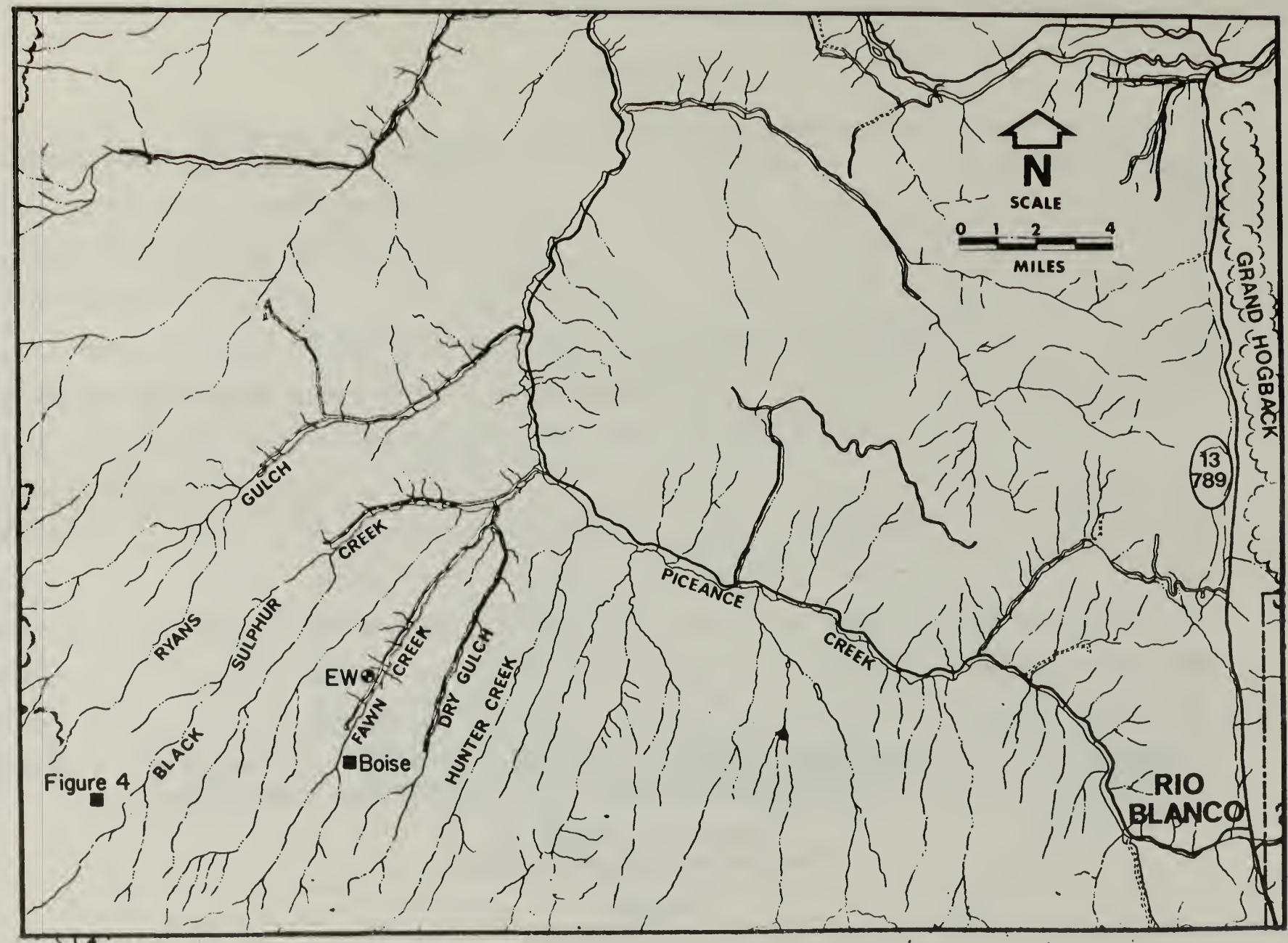


FIGURE V-4 ATLANTIC-RICHFIELD COMPANY SEISMIC STATION LOCATIONS (■), PROJECT RIO BLANCO

TABLE V-6

ATLANTIC RICHFIELD SEISMIC DATA
PROJECT RIO BLANCO

Station	Distance from EW (miles)	Sensor Used	Max. Acceleration (g) Vertical	Radial	Tangential	Remarks
Boise	2.4	Endevco (1)	2.6	*	*	Ground motion, first peak
Boise	2.4	Endevco (1)	9.0	*	*	Slap down after spall
Boise	2.4	Teledyne (2)	>1g	>1g	>1g	Instrument saturated
Figure 4	8.0	Teledyne (2)	.31	.41	.49	
Figure 4	8.0	Teledyne (3)	.30	.41	**	

(1) Q. Flex Model QA-116-15 Accelerometer and Brush Model 220, Paper Recorder.

(2) RFT-250 Strong Motion Accelerograph, Film Recording.

(3) FB-103B Force Balance Accelerometer, and Teledyne 17373 Magnetic Tape Recorder.

* Not Measured.

** Data Not Analyzed at Time of Report.

Estimated depth of alluvium at Boise site <20 ft.

Estimated depth of alluvium at Figure 4 site <6 ft.

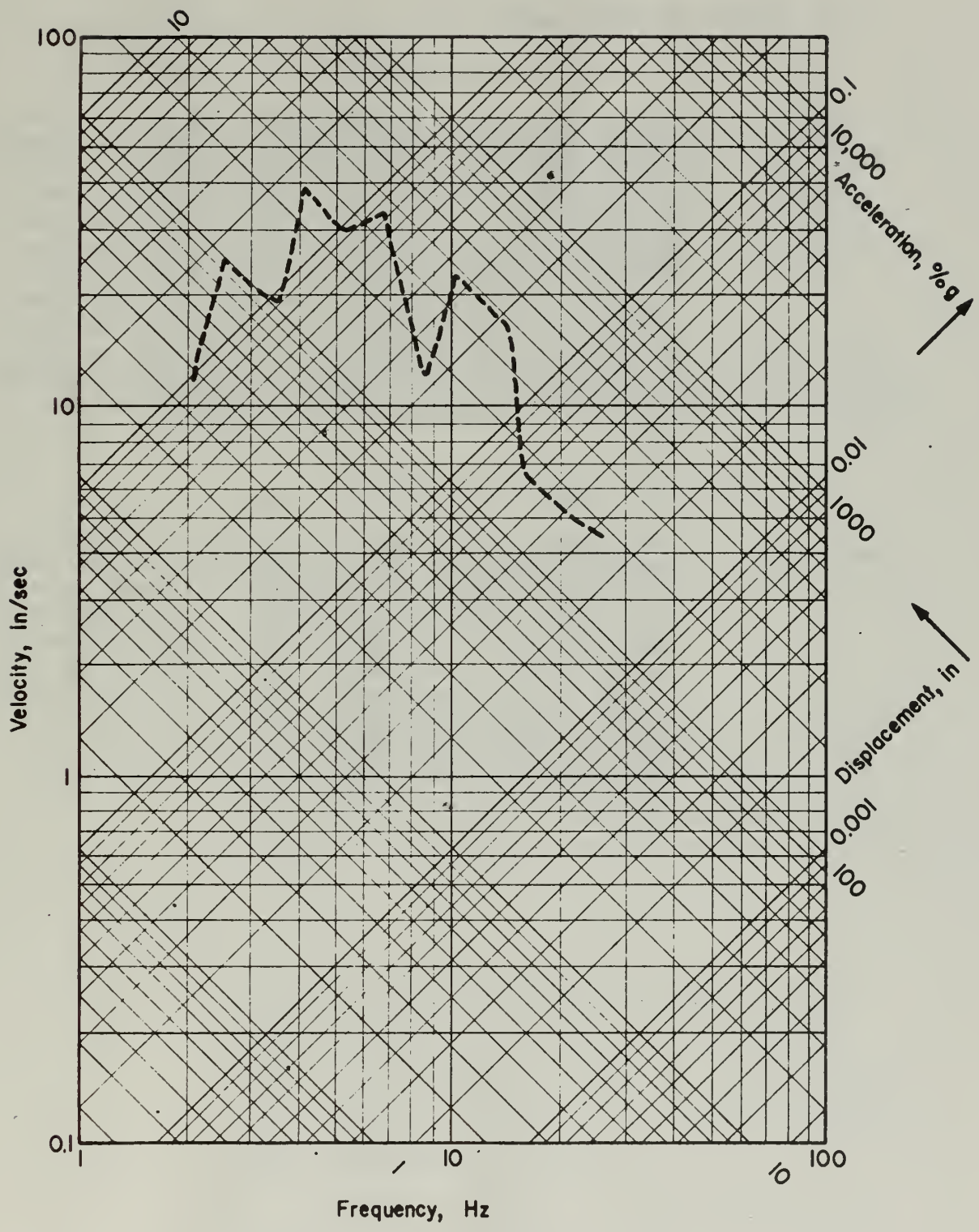


FIGURE V-5 RESPONSE SPECTRUM -- PEAK SHOCK RECORDER™ -- ENGDAHL ENTERPRISES ADD-ON PROGRAM

5-11 KENNETH MEDEARIS & ASSOCIATES

5-11-1 Structure Response Studies

KMA is conducting a research study for the National Science Foundation and the American Society of Civil Engineers on full-scale structural response to ground motion. Under this contract, USGS/SEB and KMA have instrumented the Rock School residence, Harvey Gap Dam, Chadbourne Corporation depropanizer tower, and the Rangely College Gymnasium. All but two of the recording channels operated successfully. The data obtained will be utilized in a research effort aimed at providing better insight concerning the response of structures to earthquakes and wind. Results of the study will be reported when the research is completed.

5-11-2 Site Characteristics Study

KMA is conducting a limited research investigation for the Colorado-Ute Electric Association, Inc. Under this effort, KMA placed a seismic instrument at the Hayden Power Station, approximately 129 km from the emplacement well, to measure the radial component of the Rio Blanco ground motion. A good record was obtained, the peak acceleration being .0012 g's. This record has been digitized and will be utilized in assessing some of the seismic characteristics of the Hayden site. This study has not yet been completed.

VI. SAFETY PROGRAMS--Compiled by J. Toman, LLL

6-1 LLL ON-SITE SAFETY PROGRAM

The LLL On-Site Safety Program was decreased after D-day commensurate with the degree of hazard presumed to be present at the EW area. In accordance with plans set forth in the Project Definition Plan, Eberline Instrument Corporation (EIC), the Radiological Safety Contractor, moved their access control, laboratory, and sample preparation trailers to the EW location.

The instrumentation discussed below is recorded and read out in the Access Control Trailer. Currently, daily reports are also telephoned to the LLL where the instrument readings are logged along with general site activities over the previous day.

6-1-1 Remote Area Monitoring Systems (RAMS)

Three of the D-day RAMS, Numbers 1, 2, and 3, remain on line in the vicinity of the EW. All RAMS readings to date have been negative.

6-1-2 Geophones

All geophone readouts were discontinued at D+1 after a 24-hour period in which no activity was detected. The detector heads were removed ffrom their D-day locations on D+3. Correlation of the geophone data with recorded aftershocks will be undertaken when the data from the aftershocks has been analyzed and reported.

6-1-3 Air Samplers

One operational high-volume air sampler is located 15 feet northwest of the EW. The sample head is changed daily, and is analyzed in the EIC Mobile Laboratory after an appropriate wait for Radon decay of approximately one week. All samples taken to date have read background. In the event the RAMS should display a positive reading, the air sample would be immediately analyzed.

One low-volume air sampler is located beneath the EIC Access Control Trailer, approximately 100 feet northwest of the EW. Samples from this unit are analyzed monthly by EIC at Santa Fe. This air sample is not part of the LLL safety surveillance system at the EW.

6-1-4 EW Area Weather

Wind speed and direction indicators are located approximately 100 feet east of the EW, and continuously record at the EIC Access Control Trailer.

6-2 INDUSTRIAL SAFETY

The LLL was delegated the industrial safety surveillance responsibility within the area in which LLL-directed operations were predominant, i.e., the EW pad and related facilities, during the period of about D-33 through D+5. Activities since D+5 have also been in compliance with industrial safety codes. There have been no industrial accidents throughout the entire operational period to date.

VII. FIELD OPERATIONS--Compiled by R. T. Stearns, AEC/NV, and J. Toman, LLL

7-1 LAWRENCE LIVERMORE LABORATORY EXPLOSIVES OPERATIONS

Three nuclear gas stimulation explosives were provided for Rio Blanco by the LLL. Subsystems of these units were assembled in Livermore, California, and transported to the Nevada Test Site (NTS), where the final assembly was accomplished. Required tests of the integrated control system and the explosives were conducted such that at the conclusion of the NTS assembly, the units were ready for emplacement.

7-1-1 Explosives Delivery

The explosives were transported from the NTS to the Rio Blanco EW by courier crew from the AEC Albuquerque Operations Office using a "Safe-Secure" trailer. The forecast of 23 hours for the transit time was exceeded by 15 hours, as heavy snows required a stopover in Beaver, Utah. The "Safe-Secure" trailer provided an on-site explosive storage facility during emplacement.

7-1-2 Timing and Firing System

A complete electronic systems check was conducted at the Rio Blanco site prior to release of the explosives from the NTS for shipment. This test not only utilized electronic packages similar to those contained in the explosives, but required that all dynamic measurements function as scheduled for D-day. After arrival at the EW, the condition of each explosive was monitored during and after emplacement up to the time of detonation. The timing and firing system which included the command trailer, microwave link to the emplacement well, emplacement well receiving equipment, and downhole components performed as designed.

7-1-3 Explosives Performance

Three 30-kt explosives were detonated at depths of 5,840, 6,230, and 6,690 feet below the ground surface in the EW at 1000:00.12 hours ± 0.01 seconds, MDT, on May 17, 1973. All three explosives detonated with the planned 10 microseconds delay between each. All monitored functions of the explosive system were within the range of expected values.

7-1-4 Reentry to the EW Area

The Entry Control Center (ECC) was the staging point for the initial EW area reentry operations (see Figure 1-1). All reentry teams, some 22 in total, were briefed and were in their respective vehicles at the ECC prior to detonation time.

The initial Radiological Safety survey team was dispatched from the ECC at 1020 hours and completed their survey of EW prior to 1200 hours. Due to continuing geophone noise, all reentry teams were delayed from reaching their respective stations by about 1.5 to 2.0 hours.

7-2 CONSTRUCTION AND LOGISTICS

All trailers, equipment, and facilities have been removed from the FPCP and the ECC, and the area has been restored to its predetonation condition. Seeding with sagebrush seed, according to Bureau of Land Management standards, will be done in the fall of the year. At the emplacement well, all of the equipment has been removed except those items necessary for reentry drilling and items required for the interim period between detonation and reentry. Equipment at the emplacement well at the present time includes three EIC trailers, one first-aid trailer, and the detection equipment at and around the wellhead. The wellhead has been enclosed with a building that is locked and secured.

All of the vehicles on loan from the NTS were returned to NTS and Las Vegas within one week following detonation. Much of the material either on loan from NTS or brought by participants was returned in these vehicles. Remaining Government equipment including radios, antennas, radio repeaters, etc., which was left behind will be ready for shipment to NTS or for disposal in Grand Junction sometime in July. The Government-owned radio equipment (Net 12 SYSTRAC repeaters) were removed from Monument Peak in early June and the last of the radio repeater equipment on Land's End will be removed during the first week in July.

The Government mobile radios used on the CER Nets 1 and 2 have been determined to be surplus and will be excessed through GSA in Grand Junction rather than shipped to Las Vegas for excess. The remaining equipment will be returned to NTS by mid-July. All equipment on loan to Project Rio Blanco has been accounted for.

Reentry drilling is planned to begin about mid-August and be completed by early September. Arrangements for the availability of drilling rigs in the reentry time period are being made.

7-3 AREA CONTROL

In summary, area control included the closing of the Piceance Creek road to all but authorized personnel at 0523 hours, initiation of the closed area sweep at 0530 hours, initiation of aerial security sweeps at 0710 hours, closure of the Piceance Creek road to all traffic at 0730 hours, confirmation that industrial plants were ready and mines evacuated at 0838 hours, completion of resident evacuation by 0852 hours,

confirmation that all manned stations were ready at 0905 hours, completion of aerial security sweeps at 0910 hours, confirmation that trains were stopped in critical areas by 0933 hours, confirmation that all roadblocks were activated by 0944 hours, and detonation at 1000:00.12 hours ± .01 second MDT. By 1003 hours, instructions were sent to all roadblocks to commence deactivation except those on either end of the Piceance Creek road. At 1130 hours, all residents had been advised to return to their homes and by noon the entire area was open to traffic.

To accomplish evacuation of residents from the Controlled Area (within 0.1g, 14.5 miles), CER fielded a four-man Area Control Team furnished with radio-equipped vehicles. All team members were local inhabitants, hired by CER, briefed, and equipped for their tasks about a week before the detonation date. Each member was made responsible for a particular group of residents living within 14.5 miles of the EW. Only the 30 persons residing within 7.5 miles (the closed area) were requested to leave. However, all 98 inhabitants living within 14.5 miles relocated to the observer site located near the FPCP.

After the detonation, residents were released from the observer site before other observers to return to their homes. The Area Control Team contacted each family as soon as they reached their homes to ascertain whether immediate repairs were needed. Damage turned out to be slight and emergency repairs proved unnecessary.

Traffic control was accomplished through the establishment of roadblocks at 19 locations. Two kinds of roadblocks were used:

(1) Roadblocks isolating fairly long stretches of roads which were considered either highly vulnerable or had low traffic densities. These roadblocks went into effect about one hour before detonation time.

(2) Shortblocks, i.e., roadblocks covering small road segments of high traffic density locations. These were put into effect 15 minutes before detonation time.

In addition to the roadblocks, surveillance was maintained at distant rockfall areas before, during, and after the detonation sequence by roving road patrols, Figure VII-1.

Roadblocks and surveillance personnel included members of the Colorado State Patrol, Colorado State Highway Department, Rio Blanco and Garfield County Sheriff and Road Departments, and Colorado State Division of Wildlife. The communications between the GJCP and the various roadblock units were handled by Colorado State Patrol and Highway Department personnel.

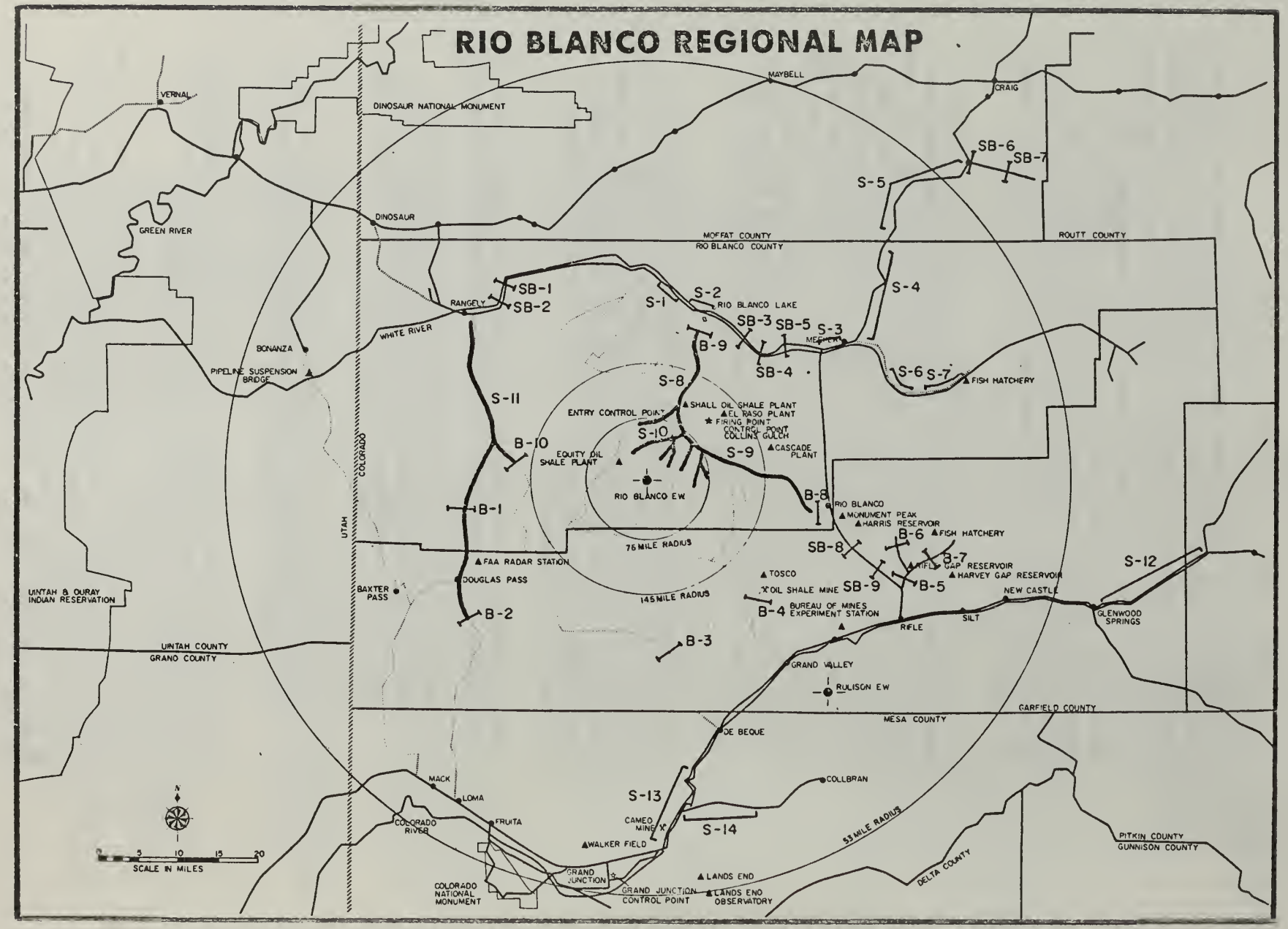


FIGURE VII-1 LOCATIONS OF TRAFFIC PRECAUTIONS

Between Palisade and Dotsero, no trains were located at vulnerable locations at detonation time. One westbound freight train was stopped in Glenwood Springs and one work train was located on a siding in Grand Valley.

Immediately after the detonation, six motorized track patrols with radio communication equipment checked the condition of the entire length of railroad right-of-way between Dotsero and Palisade. As soon as all of them reported that the track was clear and no rockfalls had been observed near the right-of-way, train traffic was resumed. All internal radio communications were handled by the Denver and Rio Grande Western Railroad radio system. The GJCP was linked with the central railroad dispatch office by telephone.

All active mines within 53 miles from the EW were evacuated during the detonation. Personnel of industrial plants within 14.5 miles from the EW and the Colony Oil Shale Plant on Parachute Creek were requested to be outside and well away from the plant structures. Verification of response to these recommendations was made by phone at least three hours before the detonation. Mine inspectors were stationed at all active mines and inspected them immediately after the detonation before allowing operations to resume.

7-4 AIRCRAFT CONTROL

Commercial and military aircraft participated as scheduled and were in designated positions at detonation time. Aircraft consisted of the following:

2 UH-1N helicopters--area observation and emergency standby.

1 Bell helicopter--area observation and road damage survey.

1 Jet Ranger--area observation.

1 Allouette helicopter--detonation-time documentary photography and bioenvironmental surveys.

1 Turbo-Beech for area surveillance and radio relay.

1 Cessna for Sandia Laboratory (SLA) postdetonation aerial mapping.

A Martin 404 and an Otter were on standby at Walker Field in Grand Junction and McCarran Field in Las Vegas, respectively.

All helicopter missions were flown from the FPCP. The fixed-wing aircraft operated from Walker Field at Grand Junction. The closed area airspace was released to FAA at 1500 hours

May 17, 1973, and final release of the aircraft was 1200 hours May 18, 1973.

The flying time on the commercial helicopters amounted to 39 hours and 10 minutes and on the USAF UH-1N to 33 hours and 35 minutes, for a total helicopter time of 72 hours and 45 minutes.

7-5 SECURITY

Twenty-nine Wackenhut guards and supervisory personnel comprising a regular guard force and an emergency alert force became operational on May 1. When the explosives were downhole, and the stemming started on May 9, the emergency alert force was disbanded.

The security force assisted in the D-1 and D-day sweeps of the closed area, establishing necessary security stations at the 7.5-mile perimeter. All security functions were terminated at H+3 hours, and classified activity terminated on May 19.

7-6 COMMUNICATIONS

Communications in support of the Rio Blanco detonation were provided by CER Geonuclear with the exception of a public information broadcast package and a Net 12 repeater provided by the NV. Basic service to the forward areas consisted of a microwave system from Grand Junction with four Grand Junction telephone numbers and two VHF radio nets. The repeaters for the radio nets were located on Monument Peak and did not provide coverage in the Grand Junction area. The systems were extended into Grand Junction on a remote basis utilizing the microwave system. At the time of the detonation, the following communications were in operation:

(1) Four telephone circuits between the FPCP and the GJCP.

(2) Three duplex VHF radio nets.

(3) A commercial broadcast feed serving seven radio stations with a capability of patching one of the telephone circuits from the FPCP into the network.

(4) A countdown feed over FTS to LLL, Livermore, California.

(5) A simplex VHF radio net for security.

(6) Terminals for the Colorado State Patrol and Colorado Highway Department radio systems at the GJCP.

(7) Commercial telephone service provided by key systems in the GJCP.

(8) At H-30 minutes, a conference circuit between the FPCP, GJCP, and the AEC Headquarters at Germantown, Maryland, was established utilizing commercial facilities.

All systems performed adequately with the exception of the dialing mechanism on one of the microwave channels providing a telephone circuit between the two CPs. The malfunction involved the inability to dial the FPCP from Grand Junction on this particular number. The problem was circumvented, however, by establishing a one-way dialing procedure.

Miscellaneous support was provided to record the press conference held by the AEC Chairman, Dr. Dixie Lee Ray.

7-7 RADIOLOGICAL OPERATIONS

At detonation time, 43 monitors were fielded from Eberline Instrument Corporation (EIC), Environmental Protection Agency (EPA), and Colorado Department of Health (CDH). EIC supported the reentry and off-site monitoring while the EPA provided a contingency backup. CDH provided observing monitoring teams in the controlled area and nearby population centers.

Approximately 20 air sampling stations were operating at the EW, nearby ranches, and towns. A variety of environmental samples were collected pre- and postshot by the above organizations. To date, all analyzed environmental samples have been background.

Thermoluminescent dosimeters (TLD) were placed around the EW area and in the surrounding areas for potential exposure evaluation. TLDs were used for personnel dosimetry during device emplacement and postshot reentry operations. No exposures above background were recorded.

The following is a description of each participating organization's activities:

7-7-1 Environmental Protection Agency (EPA)

Eleven EPA monitors were positioned, as indicated in Figure VII-2, to provide personnel control, communications, and to serve as a contingency force. An additional contingency force of eight monitors was on standby in Las Vegas to be used if required.

Three additional EPA monitors were airborne at detonation time to provide area surveillance, cloud tracking, and sampling if required.

EPA's environmental sampling consisted of a noble gas sampler, four offsite air sampling locations, milk, and surface waters.

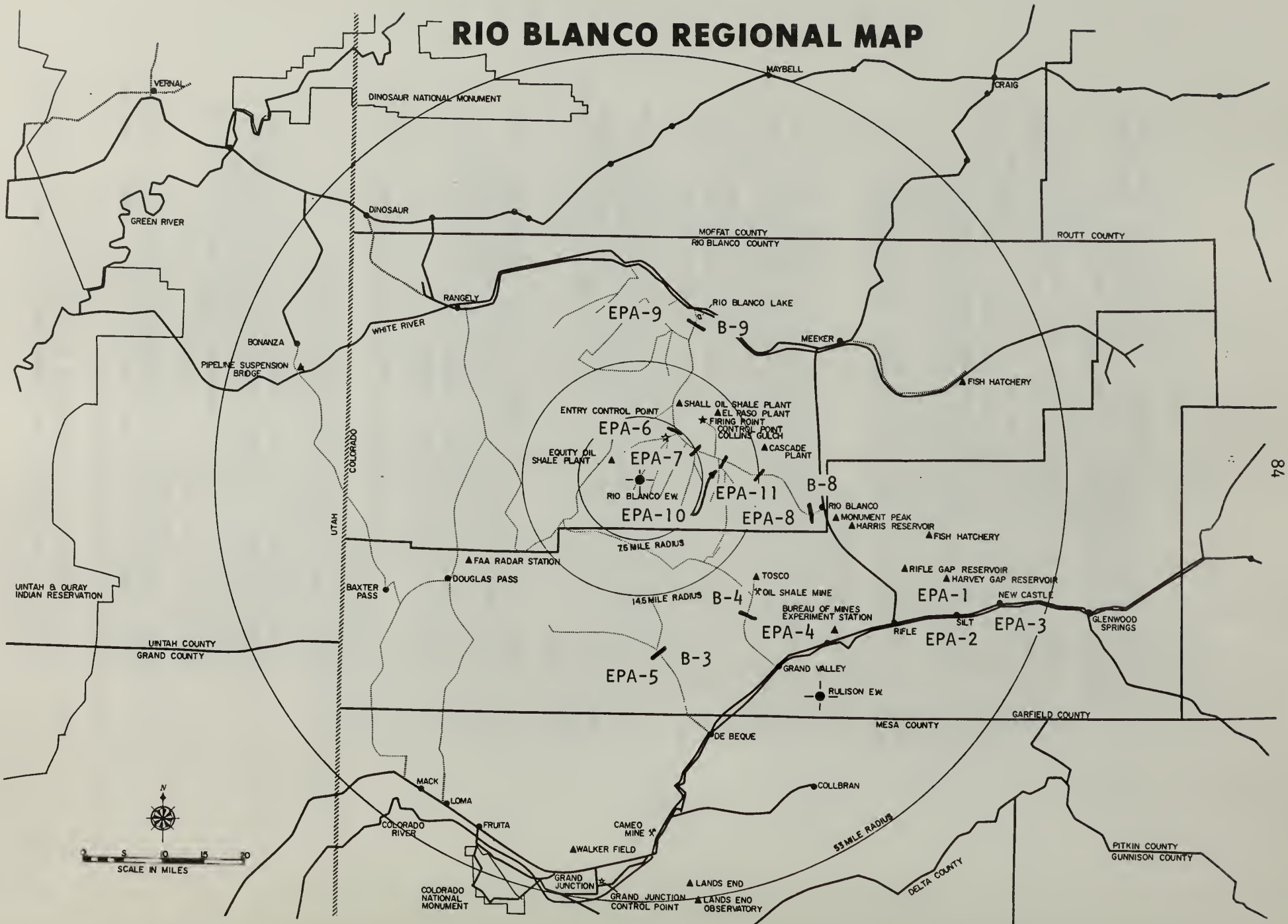


FIGURE VII-2 EPA POSITIONS

A quality assurance program for laboratory analysis of all types of samples to be collected for detonation time and production testing is underway presently. A first set of samples has been distributed to the participating laboratories at this time. A second set will be sent just prior to reentry drilling and flaring.

7-7-2 Colorado Department of Health (CDH)

Nine two-man teams equipped with monitoring instruments were fielded to participate in sampling and monitoring exercises. The CDH collected surface water samples, air moisture samples, air particulate samples, soil samples, milk, drinking water, stream sediment, and samples from municipal water supplies. Resampling was conducted at D+14 days for surface water and soil in the Fawn Creek area. All sample results at this date have been background. CDH will publish special reports covering the detonation phase and production testing phase discussing the results of their monitoring and sampling in detail.

7-7-3 Eberline Instrument Corporation (EIC)

EIC conducted a comprehensive environmental sampling program predetonation to Rio Blanco and sampled air, surface waters, soil, animal and fish tissues, milk, vegetation, etc. To date, all results have been background, with exception of activity observed in 1972, due to a Chinese atmospheric nuclear test. Details of the environmental sampling program have been published as quarterly reports.

At detonation time, 14 EIC monitors were fielded to provide reentry support (10) and offsite monitoring (4).

Monitoring support was provided on a 24-hour basis at the wellhead until D+9 and subsequently on a daily basis to the present time.

7-8 METEOROLOGY

Air Resources Laboratory-Las Vegas (ARL-LV) provided four meteorologists, six meteorological technicians, and two electronics technicians to provide operational meteorological support for the detonation and through as long a period following the detonation as was deemed necessary by the AEC Project Director (APD). Additionally, a senior ARL-LV meteorologist served on the Safety Advisory Panel.

Surface wind data were obtained from two towers located near the emplacement well, one atop a ridge about eight miles

southwest of the emplacement well, and the second near the junction of Black Sulphur Creek Road and Piceance Creek Road.

Upper air soundings of pressure, temperature, humidity, and winds were made at a weather observing station established at the ECC, and the capability of measuring upper winds at any two of several offsite locations around the periphery of the Rio Blanco site was maintained.

A daily weather forecasting service was provided and weather briefings were presented, at both the GJCP and FPCP, as required. ARL-LV meteorologists were also prepared to provide predetonation estimates of potential radiological exposure using the LLL seepage model and real-time estimates should any seepage have occurred after detonation.

The weather at detonation time was as follows: "High pressure, at the surface and aloft, over the western United States produced northwesterly upper winds and partly cloudy skies over western Colorado. Surface air temperatures were in the low sixties.

Surface winds in Fawn Creek at and after detonation time were northwesterly at very light speeds. Surface winds in the general vicinity were light and variable."

ARL-LV meteorologists and weather observers remained in Grand Junction in an on-call status until released by the APD on D+4 days. Under the persistent stable atmospheric conditions resulting from the high pressure system, understanding of daytime and nocturnal stability and wind conditions was sufficient to allow dismantling of the ARL-LV meteorological measuring equipment beginning on D+1 day.

All ARL-LV personnel departed the Grand Junction area by D+4 days.

VIII. PUBLIC INFORMATION--Compiled by D. G. Jackson, AEC/NV

8-1 PUBLIC AFFAIRS PROGRAM

8-1-1 Joint Office of Information

AEC/NV and CER conducted the Rio Blanco public affairs program under a Joint Office of Information. All information and public affairs activities conducted during Project Rio Blanco were coordinated through the JOI. The operational JOI was established at the Grand Junction Control Point on April 9. A separate CER office was established in Meeker on the same date.

8-1-2 Public Meetings

Public meetings were held between April 17 and 26 at the Rock School, DeBeque, Meeker, Rangely, Rifle, and Grand Valley. Briefings were conducted by project officials from the AEC, CER, LLL, and CDH. The briefings emphasized the predicted effects of the detonation upon the local area. The meetings were well advertised but attendance was generally small.

8-2 NEWS MEDIA ASSISTANCE

8-2-1 Project Definition Phase

News media representatives from printed and broadcast media reported on Project Rio Blanco from its inception. Periodic visits to the Rio Blanco area during the project definition phase to accompany newsmen were made by members of the JOI. Public announcements were made as necessary giving major actions concerning the project.

8-2-2 Operational Phase

With the establishment of the JOI at the GJCP, daily contact was maintained with local, state, and national news media. Press tours to the emplacement well were conducted on May 4 during the emplacement of the second nuclear explosive; on May 16 to explain final test preparations; and on May 17, D-day, following the detonation. The JOI arranged a press conference conducted by AEC Chairman, Dr. Dixy Lee Ray, on May 16.

8-2-3 D-Day News Coverage

An observer program was conducted for approximately 300 members of the public and 50 news media

representatives. The observer point was located at the end of an airstrip about 3,500 feet from the FPCP.

The predetonation briefing was conducted at H minus 1/2 hour by the LLL Project Scientist. The observers heard the LLL live countdown. The postdetonation briefing was presented at about H plus 45 minutes by the AEC Project Director. AEC Chairman Ray made a postdetonation statement and answered questions at about H plus 1 hour.

No special arrangements were made for live coverage of the detonation by news media. Network and state television news representatives requested and received assistance in setting up cameras at various locations near the emplacement well. The project provided aerial motion picture footage of the emplacement well at H-hour to all television news media on a pool basis. CER provided a helicopter to transport TV correspondents from the observer point to Meeker to enable them to fly to Denver by chartered jet to meet broadcast deadlines.

8-2-4 Commercial Radio Broadcast Network

A commercial radio broadcast network was established by the JOI to provide timely information on the project safety program and D-day activities. Radio stations in Grand Junction, Rifle, Craig, Denver, and Vernal, Utah, received simultaneous broadcasts at 1230 hours on May 16 and at 0610, 0710, 0810, 0910, 0945, 0958, and 1030 hours on May 17. The countdown was broadcast live from the FPCP.

8-2-5 Postdetonation Information Program

The JOI at the GJCP was manned by project information personnel for two weeks following D-day. Information on the effects of the experiment and on claims resulting from the detonation were released to local and area news media. The JOI will continue to operate from Las Vegas throughout the flaring operation.

Form 1279–3
(June 1984)

BORROWER

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